

THE PREPARATION OF ATHLETES WITH CEREBRAL PALSY FOR ELITE COMPETITION

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Declaration

I, the undersigned, hereby declared that the work contained in this dissertation is my own original work and that I have not previously in its entirety or in part, submitted it to any university for a degree.

Signature

Date

Abstract

Sport performance management has emerged as a specialization in sport science that is focused on providing the athlete and coach with optimal information about training programmes and the support services needed in order to pursue excellence. As a more professional approach to disability sport has grown with the international status of the Paralympics, sport performance management dealing specifically with athletes with disabilities requires development.

The purpose of this study was to focus on documenting the delivery of sport science support for three cyclists with cerebral palsy training for the Athens Paralympics. A case study approach was taken in this research that provided sport science support to three cyclists. Documentation of the training experience of each cyclist over 18 months of training leading up to the Games, was accomplished by quantification of daily training as well as periodic laboratory testing. A comprehensive picture was drawn of training intensities, modalities and frequencies for each cyclist during each macro-cycle, with special attention to the following three variables.

Power output and lactate

Power output and VO₂ max

Peak and mean sprint power output (Wingate test)

Two of the three cyclists perceived the support they received to have been critical to the success of their preparation. The investigator concluded that sport management has an important role to play in the development of disability sport at the elite level, and that a lot more hard training is possible for cyclists with cerebral palsy, than some coaches may have previously believed, especially in terms of intensity and duration.

Opsomming

Sport prestasie bestuur is 'n nuwe veld in sportwetenskap wat daarop fokus om die atleet en afrigter optimaal te ondersteun met informasie rakende oefenprogramme, sowel as die ondersteuning van sportwetenskaplike dienste om die maksimale prestasie tot gevolg te hê. Die internasionale status van die Paralimpiese Spele het die afgelope jare gegroei en sport prestasie bestuur vir atlete met gestremdhede fokus daarop om hierdie atlete te ondersteun tot 'n meer professionele benadering ten opsigte van hulle oefening en deelname aan kompetisie.

Die doel van die studie was om sportwetenskaplike dienste wat gelewer is ter voorbereiding van die Paralimpiese Spele in Athene, aan persone wat serebraal gestremd is en fietsry, aan te teken. 'n Gevallestudie benadering is gevolg om hierdie dienste vir elke fietsryer aan te teken. Die oefen ervaring vir die 18 maande wat die Paralimpiese spele voor afgegaan het, is opgeteken. Die monitor van daaglikse oefening sowel as laboratorium toetse was gebruik om die oefen ervaring te kwantifiseer. 'n Volledige prentjie van die oefening is verkry deur die oefen intensiteit, tipe oefening en die frekwensie van oefen vir elke makrosiklus aan te teken. Spesiale aandag was geskenk aan die volgende fisiologiese veranderlikes tydens die laboratorium toetse:

Krag en laktaat

Krag en VO_2 maks

Krag en gemiddelde naelry krag (Wingate toets)

Twee van die drie fietryers het die ondersteuning van kardinale belang geag vir hulle voorbereiding vir die spele. Die navorsing dui daarop dat sport prestasie bestuur 'n belangrike rol kan speel in die ontwikkeling van sport vir persone met gestremde op 'n top vlak. Daar is ook 'n groot moontlikheid dat serebraal gestremde fietsryers 'n hoër oefenlas kan hanteer as wat voorheen geglo is.

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Father, I surrender it all to You.

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Suzanne Ferreira

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Chapter One

The Problem

All athletes strive to improve from a starting point to reach the limits of their potential. Their tools are effective training, a sound nutrition plan, the right outlook and suitable equipment. You cannot plan the genetic potential that your parents bestowed you. But you can certainly plan strategies to rise to the optimal level. (Hawley & Burke, 1998: xvii)

It is widely accepted that the design and implementation of carefully selected strategies for training can have a critical impact on the quality of sport performance (Liow & Hopkins, 1996). It is one of the goals of the sport scientist to provide accurate and reliable information on which to base decisions about which training strategies to select and how to implement them in an athlete's training. Sport scientists also make recommendations about the types of interventions that may help an athlete improve.

Increased attention to the scientific approach to training has led to the development of a focus within sport science that has been described as "sport performance enhancement," where the effects of training, biomechanical adaptations, the impact of nutrition, psychology, or any other treatments are monitored in order to determine if an athlete is performing to his/her ability (Hopkins, Hawley & Burke, 1999). Bompa (1994) noted that increases in the standard of performance in many sports can be attributed to improvements in coaching, and that "Coaching has become more sophisticated partially from the assistance of sport specialists and scientists" (p. 3). However, the role of sport science in the preparation of high performance athletes remains somewhat controversial. When financial support is limited, athletes may wonder if it is worth spending money on sport science services, or if it would be more beneficial to invest all financial resources in better equipment and coaching. This question was explored in the popular newsletter *Peak Performance* (July, 2004), in an article entitled "What have the sport scientists done for us?" (p. 1). This article posed questions such as: Do sport scientists really take the knowledge of science and put it into practice? Are they able to have an impact on sport performance? If not, what can be done to increase the influence that sport science can have on high performance athletes?

One response to this challenging situation is the development of a role within high performance sport that can be labelled the “sport performance manager.” British Athletics, for example, recently advertised an opening for a “Senior Performance Manager – Disability,” (<http://www.ukssport.gov.uk/jobs>, retrieved Sept. 16, 2005). The qualities of the performance manager were described as “an in-depth understanding of the requirements of elite athletes and how that knowledge can be applied to produce results” and “the ability to deliver a world-class plan for Paralympic success”(no page).

This dissertation will report on the efforts of the investigator to function as the performance manager for three elite level cyclists with cerebral palsy, during their preparation for the 2004 Paralympic Games. This introductory chapter provides background information about competitive sport for persons with disabilities, and a conception of the scope of sport performance management within the training of elite level athletes. Following the presentation of the research question, a brief presentation of the methodology, limitations of the study and definitions of terms are presented.

Competitive Sport for Persons with Disabilities

The beginning of competitive sport for persons with disabilities is usually traced to 1944 when the Stoke Mandeville Hospital in England routinely used competitive sport as part of the physical therapy during the rehabilitation of soldiers in their spinal cord unit (Dompier, 2001). By 1948, Sir Ludwig Guttman invited the World War II veterans with spinal cord injuries to participate in the first formally organized games at Stoke Mandeville, England (NCPAD, <http://www.ncpad.org/factshtml/paralympics.htm>, retrieved May 8, 2003).

Today, the showcase of achievements in sport for individuals with disabilities is the Paralympic Games, the equivalent of the Olympic Games (Goodbody, 2004). The first Paralympic Games were in 1960 in Rome, where 23 countries and 400 athletes competed. In 1972, the Heidelberg Paralympic Games included 43 countries and 984 athletes. By the time of the Sydney 2000 Paralympics, 123 countries and 3 839 athletes competed in the Games. More than 1.2 million spectator tickets were sold for the Sydney Paralympics, which indicated the growth of spectator interest in sport for persons with disabilities (Goodbody, 2004). Today, the summer and winter Paralympic Games are held in the same year as the summer and winter Olympic Games, and offer elite level competition for six

different disability groups in 17 summer sports and 3 winter sports (NCPAD, <http://www.ncpad.org/factshtml/paralympics.htm>, retrieved May 8, 2003). Athletes with disabilities are now seen as capable of becoming high performance athletes. It is therefore important that research in the field of disability sport keep up with what is happening in sport science and sports medicine. This will require specialist knowledge and a commitment to explore means for the enhancement of performance, specifically in disability sport.

There has been growing interest in the study of disability sport within sport science. The *Canadian Journal of Applied Physiology* (1998) devoted an entire journal to the edition of the subject of physical assessment and training programmes for individuals with disabilities. The journal highlighted the inability of many fitness specialists to provide individuals with disabilities with appropriate fitness assessments and exercise programmes. Liow and Hopkins (1996) concluded that little is known about the training practices of athletes with disabilities and that there is a need for improvement in coaching and training of many top-class athletes with disabilities. This position was supported by Rimmer, Braddock and Pitetti (1996), who called for more research on the activity patterns and physiological responses to exercise of persons with disabilities.

Sport for persons with disabilities relies on a classification system that creates fairness in competition. Classification is based on an initial assessment of each athlete's abilities in relation to the sport in which they want to participate. This approach promotes equity in competition because athletes will compete against "similar others" in terms of movement potential in a specific sport. This approach also provides an incentive to all serious athletes to train as hard as they can to achieve excellence within their class. However, although athletes are grouped into classes for competition, it must be acknowledged that each athlete's particular disability does make them unique. This uniqueness is particularly evident when working with persons with cerebral palsy, such as the cyclists who were the subjects in this study. Sport scientists must take the classification of each athlete into account in the design, implementation and interpretation phases of any research project (Rossouw, 2001).

Cerebral Palsy

Cerebral palsy is a disorder of the central nervous system. The incidence of cerebral palsy in the United States was estimated by United Cerebral Palsy (2001) to be 764 000 children and adults. This organization reported that nearly 8 000 babies and infants are diagnosed with Cerebral Palsy each year in the United States, with another 1 200 – 1 500 children diagnosed at preschool age.

Although cerebral palsy is not progressive and not contagious, historically it has been regarded as a “long term, non-fatal, non-curable disease” (Cruickshank, 1980, p.2). Cerebral palsy is currently referred to as a condition, not a disease. A specific definition for cerebral palsy is difficult because the areas of brain lesions and the effects of those lesions on behavior, differs tremendously among individuals. Intellectual impairment, speech impairment, emotional impairment, psychological difficulties, deafness, blindness, etc., are all factors that may or may not accompany the motor impairment that is associated with cerebral palsy.

Horvat (1990) defined cerebral palsy as:

...a group of conditions that originate in infancy and are characterized by weakness, paralysis, lack of coordination, motor functioning and poor muscle tone directly related to pathology of the motor control centers of the brain (p. 205).

Although cerebral palsy is not “curable”, training and therapy can help improve the functioning of the muscles and nerves. Hadders-Algra (2000) advocated participation in physical activities as one way to enhance the capacity of the individual with cerebral palsy to adapt his/her motor behaviour to the environment.

Cycling for Athletes with Cerebral Palsy

Cycling is one of the 17 sports included in the Summer Paralympic Games. Cyclists with amputations, visual impairments and with cerebral palsy compete in their own classes to ensure that skill, tactics and fitness will be the critical determinants of who wins. In the beginning of 2005, South Africa was ranked as 10th out of 43 countries in the world in the road races for males with cerebral palsy, and 13th in the track races for males with cerebral palsy (<http://www.IPC.org>, retrieved on January 27, 2005). This is an indication that South Africa is a force to be reckoned with in the world of cycling for

individuals with cerebral palsy. The fact that almost no scientific literature is available regarding the training of cyclists with cerebral palsy, as well as the investigator's desire to help the cyclists achieve their optimal performance, were the major motivational factors behind this research.

In many sports race time is repeated track of performance, with cycling it is not that simple. Competition varies regarding surface, terrain, weather condition, distances covered as well as tactics that is used. For cyclists with cerebral palsy the lack of competition makes it difficult to use the ranking system as a method to assess performance. It is for this reason that laboratory based performance tests were used in this study.

Sport Performance Management

Achievement at the top level in sport has been described as the product of years of training, guided by the integration of sport science with smart coaching (Goldsmith, 2001). In terms of sport performance enhancement, it is not clear that one sport science discipline is more important than any other. Goldsmith (2001) proposed that sport science and sports medicine be integrated when dealing with athletes, and not presented as separate aspects making different contributions to performance enhancement. He did not suggest that specialization among sport scientists be restricted, because focus areas must be developed in order to generate expert knowledge. He did suggest that the limitations on a specialist's ability to see the "whole picture" of sport performance be recognized and that there must be someone who takes responsibility for the integration and application of expert knowledge and services in real sport contexts.

When one considers Goldsmith's (2001) comments, sport performance management can be seen as an effort to bring knowledge from the different fields of sport science and sports medicine to the coach and athlete so that changes can be made in their preparation for competition. Sands (1998) described this approach as total quality management. If the "product" of the coach and the athlete is the performance of the athlete in the competition, then the "product" of the performance manager (or specialist) is implementing an integrated approach that helps the athlete achieve his/her potential in competition.

Bompa (1999) defined the role of sport performance management in terms of the manipulation of those direct and supportive factors that he believed play a role in systematic training (see Tables 1 and 2). Bompa (1999) also created a model to help coaches understand the different sources of variables that can affect the quality of an athlete's training (see Figure 1). Although it is outside the scope of this dissertation to critique the Bompa (1999) model, it is interesting to note that he does identify "findings from science" as one source of influence on the quality of training sessions. Sport performance managers seek to optimize quality of training through the manipulation of selected direct and indirect factors in the planning and implementation of a systematic approach to training.

Table1. An adapted summary of the direct factors involved in systematic training (Bompa, 1999, p. 13)

Direct Factors			
Training Factors		Evaluation Factors	
Access to coaching/teaching	Basic physical training	Scientific Assessment	Video analysis
Technique	Functional training	Field tests	Training Journal
Tactics	Development of relevant motor abilities	Medical Support	Self-assessment
Planned training			

Table 2. An adapted summary of the supportive factors involved in systematic training (Bompa, 1999, p. 13).

Supportive Factors			
Administration and Economic Factors		Professional Life and Life Style Factors	
Administration of the sport	Access to proper training facilities	Occupational or school satisfaction	Diet
Organisation of the club, team, etc.	Appropriate Equipment	Organisation of a daily programme	No smoking and/or drinking
Financial support	Appropriate Clothing	Amount of rest	Physical activity
Opportunities for organised competitions	Facilities for other physical activities		

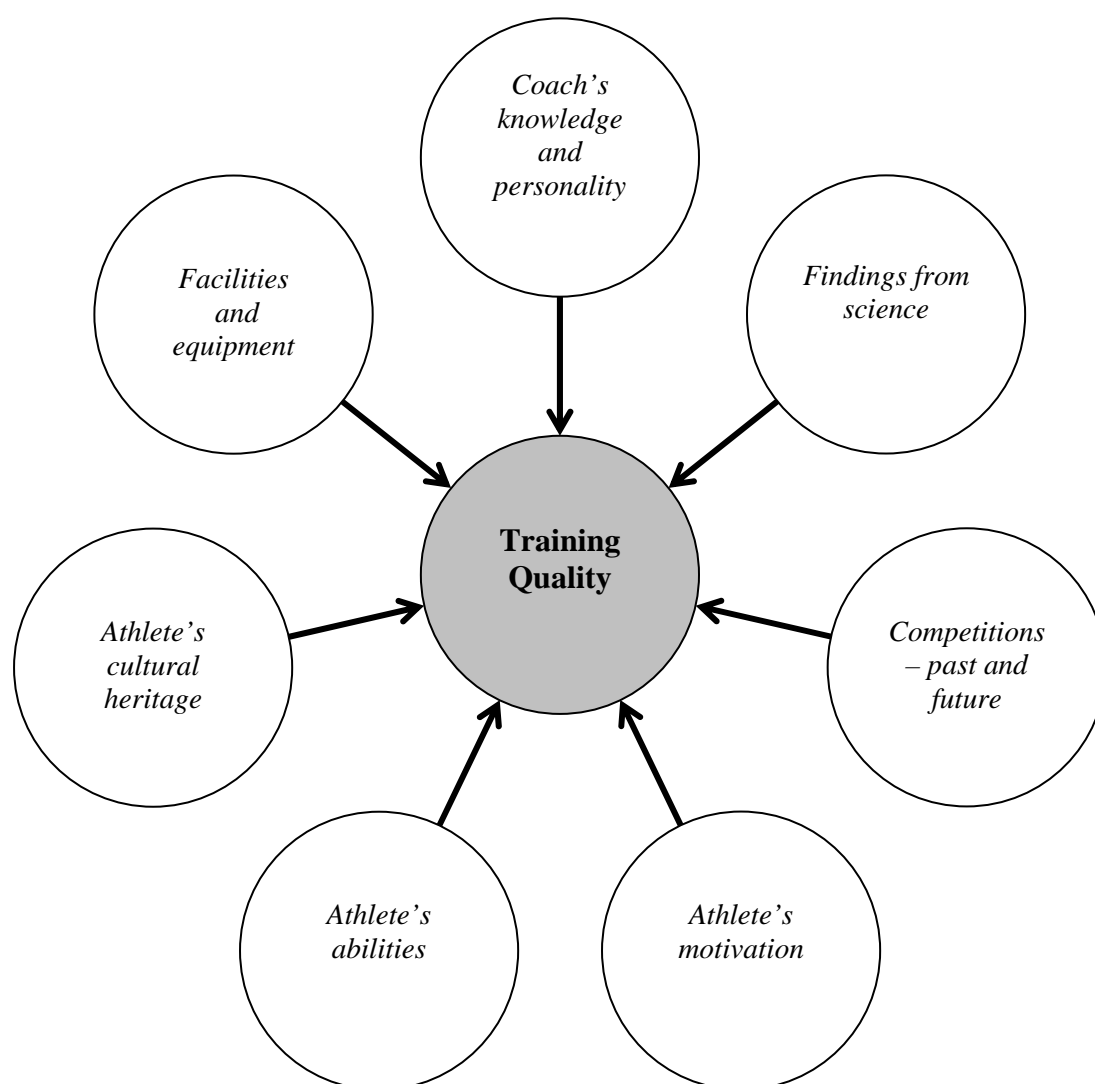


Figure 1

An adaptation of Bompa's (1999) conceptualization of the sources of variables that can affect the quality of an athlete's training (p.13).

Purpose of the Study

The purpose of this study was to support the training of three high performance cyclists with cerebral palsy through the services of a sport performance manager who helped them systematize their training. Jeukendrup (2002) stated that apart from genetic

endowment, no factor plays a more important role in cycling performance than the physiological adaptations induced by training. Training factors like intensity, duration, frequency, specificity and type of training are typically manipulated for able-bodied cyclists, so it can be assumed that this will be the case for athletes with disabilities.

Sport performance management is aimed at developing a system of training to help the cyclists and the coach to evaluate the training programme by means of assessment. Assessment of the different components necessary to perform in cycling combined with suggestions of interventions of how to improve these weaknesses are ways of evaluating the effectiveness of a periodised training plan. If current training does not improve the performance, the reason for lack of improvement needs to be discussed and new methods implemented.

Significance of the Study

If sport for persons with disabilities is to continue to be developed to the elite level, it will require the same professional approach and the same goal of excellence in competition that characterizes the “able-bodied” sports. This means it will require the involvement of sport science and sports medicine support in planning and implementing a systematic approach to training. Toufexis and Blackman (1992) described the field of sport science in the following way:

The pulsating industry of sport science is pushing the outer limits of human performance.... Fast disappearing are the days when an elite athlete was simply the product of hard work, a gruff coach and little luck. Today science has become an indispensable part of the formula for more and more world-class competitors, who find that the margin between gold and silver is often a centimeter or a hundredth of a second. Helping mold athletes today is a growing army of specialists – from physiologists and psychologists to nutritionists and biomechanists. The result: athletes who are training not just harder, but smarter. (p.5)

Sands (1998) remarked that it is unfortunate when sport scientists see themselves as the providers of information and the coaches as the recipients of that information. He described the problem, as seen from the coaches' point of view, to be a situation in which the scientist never buys into a long-term plan to see if the sport science services provided were really beneficial to the athletes' performance. In other words, scientists might not feel any obligation to apply the outcomes of scientific research to practice. When

opportunities for interactions between coaches and scientists are created, he noted that scientists were criticized because they tended to communicate in scientific jargon that was not always understandable for the coaches.

The role of the performance manager is proposed to be the link that will allow sport scientists to specialize and expand the knowledge base about high performance sport through research, because the performance manager will take responsibility for applying sport science in the actual training situations through interaction with coaches and athletes. The performance manager will systematize training through the manipulation of direct and indirect factors, and try to support the development of the high performance athlete.

Although sport and fitness opportunities for individuals with cerebral palsy are increasing, the knowledge about their physiological responses during exercises is limited (Dwyer & Mahon, 1994). Each person with cerebral palsy tends to be unique in terms of their own abilities, and may be similarly unique in the ways in which they adapt to training. Research regarding training methods, adaptations, responses to training, as well as factors that influence the performances for cyclists with cerebral palsy is needed (Liow & Hopkins, 1996). Research regarding sport science and the effect of interventions on performance in actual competition is also lacking (Hopkins et al., 1999).

Research Question

Can a sport performance management system that targets selected direct factors, be implemented successfully with cyclists with Cerebral Palsy in their preparation for competition at the elite level?

Selected direct factors:

- Performance assessment.
- Periodised planning of training.
- Feedback on training (training logs).
- Training sessions.
- Training camps.
- Sports medicine services and products.

Methodology

This research takes the design of a descriptive evaluative case study (Thomas & Nelson, 2001) and can be categorized as applied research (Barlow & Hersen, 1987). It is accepted in applied research that individual behaviour is a function of multiple factors and the interaction of events (Barlow & Hersen, 1987). This means that variability within each individual is expected and that there is no illusion that all the factors that affect behaviour can be controlled (Barlow & Hersen, 1987). Because the subjects in this study all had cerebral palsy, itself a source of variation, and because the topic was focused on elite level cycling, the subject pool was so small that the case study method was adopted. A case study approach was also considered because sport performance management requires in-depth knowledge regarding each individual cyclist and his training regime, in order to make a contribution to his preparation for elite level competition.

A literature search was completed to gain knowledge about cerebral palsy and high performance cycling, including the identification of an approach to periodisation of training and recommended physiological assessments for cyclists. Three elite level cyclists with cerebral palsy volunteered to participate in this study. Each cyclist participated in physiological assessments on a regular basis to determine the effects of their specific training programme on their performance. Feedback regarding their performance on the physiological assessments was given, and suggestions were made about how to modify practice. The success of this implementation of sport performance management in support of the preparation of these cyclists for the Paralympics, was determined subjectively.

Limitations

The following limitations had an impact on the study:

1. There has been very little research completed on adaptations to training for persons with cerebral palsy. This meant that the investigator had to try to adapt current literature about cycling and about cerebral palsy to the subjects in this study.
2. The case study method was adopted for this study. This means that the motivation and interest of each cyclist had a profound effect on the investigator's efforts to serve as their performance manager. It also meant that generalization of the outcomes of this study must be made carefully, since there was no control group.

3. Data had to be gathered from each cyclist regarding his daily training. Incomplete training logs from the cyclists limited the accuracy of this information. More detail could have provided more insight into the specific goals for each day's training if more precise information about daily training had been gathered.
4. The role of the coach is crucial to the success of the performance manager. One of the cyclists had no coach, one had a supportive coach and one of the cyclists had a coach who did not see the benefit of sport performance management. The degree of support from a coach will influence the impact of performance management.
5. The Paralympic Games in Athens, 2004, can be seen as both a positive motivational factor as well as a limitation. Because the Paralympics is a high profile competition, two of the cyclists were unwilling to make recommended modifications to training as the Games approached out of concern that any changes in their training might have a negative impact on their performance.

Definitions

High Performance Sport for Persons with Disabilities

Sherrill (1999) defined excellence in disability sport as synonymous with Paralympics. "An athlete who falls into this category meets the following criteria: The athlete demonstrates and intense desire to excel, to perform at standards approaching personal limits and to compete near or above the highest level of excellence for a particular event within his/her sport classification" (Sherrill, 1999, pp. 206-207).

Cerebral Palsy

Winnick (2000) defined cerebral palsy as "...a group of permanent disabling symptoms resulting from damage to the motor control areas of the brain. The term 'cerebral' refers to the brain and 'palsy' to a disordered movement or posture" (p. 182).

Training

Hawley and Burke (1998) defined training for serious athletes as "...a systematic, planned program of physical preparation based upon sound scientific principles for the sole purpose of improving sport performance" (pp. 33-34). "Training is very different from

simply exercising or performing a workout; it is well planned and there is a clearly defined goal” (Jeukendrup, 2002, p.3).

System of Training

Bompa (1999) defined a system of training as: “an organized or methodically arranged set of ideas, theories or speculations. A system should encompass accumulated experience as well as pure and applied research findings in an organized whole” (p. 10).

Training Adaptation

Bompa (1999) defined a training adaptation as “the sum of transformations brought about by systematically repeating exercises” (p.13).

Determination of Success

A successful implementation of sport performance management will be measured by the “product” of the managed factors. In some cases, this could be the medals and athlete wins. In this study, it is perception of the value of performance management, as well as performance in the laboratory assessments. The product therefore includes changes in laboratory test results.

Conclusion

As competition for athletes with disabilities begins to push the limits of athletic abilities, the precision measurements made possible by sport science will become an increasingly common tool in the enhancement of performance in disability sport. The lack of knowledge regarding training aspects for cyclists with cerebral palsy as well as factors influencing the performance of these cyclists was the investigator’s motivation for the study. The greatest challenge is to bring all different factors under one umbrella to plan training sessions that can enhance performance. The aim of this study was to investigate the effect of sport performance management on selected direct factors in the preparation of cyclists with cerebral palsy for Paralympic competition.

Chapter Two

Review of Literature

A literature review was conducted to gain more knowledge about what research had been completed in the fields of cerebral palsy and cycling for individuals with cerebral palsy. Recent studies regarding the physical aspects and energy systems important for cycling were read to determine how training might influence the physiological aspects important for performance. Technical and tactical factors that influence cycling performance were then considered. The last part of this chapter presents Bompa's (1999) conceptualisation of periodisation of the training year. The factors important for training, as well as the planning, monitoring and quantification of training, are discussed under this section on the training year.

Cerebral Palsy

Cerebral palsy is defined as a group of neuromuscular disorders caused by non-progressive brain defects or lesions (Bartlett & Palisamo, 2002; Pelligrino, 2000).

Cerebral palsy is an umbrella term covering a group of non-progressive, but often changing, motor impairment syndromes secondary to lesions or anomalies of the brain arising in the early stages of development. (Hadders-Algra, 2000, p. 207)

This condition known today as cerebral palsy, was unnamed for years. Various examples from medical history have been cited where conditions that physicians suspected were caused by brain lesions, in retrospect might have been cerebral palsy (MacDonald & Chance, 1964). In 1862, a senior physician of the London Hospital made the following clinical description of a child:

... stiff, spastic muscles in the legs and to a lesser degree, the arms. The child had difficulty grasping objects, crawling and walking and did not get better or worse as he/she grew older. (United Cerebral Palsy, 2001, retrieved March 9, 2005 from http://www.ucp.org/ucp_generaldoc.cfm/1/9/37/37-37/447,no page)

The "disease" he described was then known as Little's Disease (today known as spastic diplegia). The term cerebral palsy came into use in the 1940's, especially in the United States (Cruickshank, 1980; MacDonald & Chance, 1964). The word "cerebral"

refers to the brain and “palsy” describes the lack of muscle control (MacDonald & Chance, 1964). According to Blencowe and Sheldon (cited in Cruickshank, 1980), the term “palsy” is an abbreviation of “paralysis” with reference only to movement and it means “a loss of motion or sensation in a living part or member” (p. 3). The definitions developed by Denhoff (cited in Cruickshank, 1980) may help clarify the nature of cerebral palsy:

- Standard Definition: “...a condition, characterized by paralysis, weakness, incoordination, or any other aberration of motor function due to pathology of the motor control centers of the brain” (p. 1).
- Limited Definition: “...a condition in which interferences with the control of the motor system arise as a result of lesions occurring from the birth trauma” (p. 1).
- Practical Definition: “...one component of a broader brain-damage syndrome comprised of neuro-motor dysfunction, psychological dysfunction, convulsions, or behavior disorders of organic origin” (p. 1).

Steadward (1998) stated that cerebral palsy is “...a nonprogressive, lifelong physical disability of movement and coordination that develops before, during and immediately following birth” (p. 140). According to Pitetti, Fernandez & Lanciault (1991), cerebral palsy is a physical disability that refers to a group of neuromuscular disorders caused by damage to the motor areas of the brain.

When reading the different definitions of cerebral palsy, and there are many, the following characteristics are common in a number of references (Sherrill, 2004; Wilston, 1999; Miller & Bachrach, 1995).

- There is an injury to motor areas of the brain that control muscle tone and spinal reflexes.
- It is a disorder of movement, posture, coordination and balance.
- It is non-progressive.
- It is non-contagious and non-hereditary.
- It is caused by an injury to an immature brain (before age of 16 years and usually before, during or shortly after birth).

The injury to the motor area of the brain contributes to the development of abnormal reflexes and/or the retaining of primitive reflexes. The imbalance among reflexes interferes with the development of voluntary muscle contraction and normal postural reactions. This interference results in difficulty with coordination and integration of movement patterns. The result is an apparent lack of coordination, loss of balance, muscle co-contraction and muscle weakness (Sherrill, 2004).

Poretta (2000) and Steadward, (1998) identified the following physical characteristics as typical of persons with cerebral palsy:

- Delayed development of postural reactions and reflexes.
- Abnormal posture and muscle tone.
- Contractures and a decrease in joint range of motion.

According to Sherrill (2004) and Wilston (1999), the motor areas of the brain are not always the only areas affected by injury and additional disabilities can present in a person with cerebral palsy, such as:

- Intellectual impairment.
- Seizures.
- Visual impairments.
- Auditory impairments.
- Behavioural problems.
- Communication problems.

The degree of disability also differs among persons with cerebral palsy. Cerebral palsy is classified into one of following three categories according to the degree that it affects the persons daily living (Wilston, 1999):

1. Mild: Individuals who can live and travel independently, are able to communicate, succeed in mainstream education and who have an IQ of 70 or higher.

2. Moderate: Individuals need support for daily living, use a self-propelled wheelchair, have limited hand function, can only communicate in words or phrases and need supported employment.
3. Severe: Individuals have no-purposeful hand function, may need a propelled wheelchair, are dependent on assistance for daily living, cannot communicate effectively, need special education facilities and have no employment possibilities.

Causes of Cerebral Palsy

Because cerebral palsy is caused by injury to the brain, there are no inherent problems with the muscles or nerves. It is the faulty development or damage to the motor areas of the brain that disrupts the brain's ability to adequately control movement or posture (Pellegrino, 2000). The injury that causes cerebral palsy usually occurs as a result of pre-birth, during birth or shortly after birth events that affect the brain (Pellegrino, 2000). In tracing the history of medical beliefs about the causes of cerebral palsy, United Cerebral Palsy (2001) described the following sequence:

- When Dr. Little first identified this “disease” in the 1860, he noted that most of the children with this “disease” had experienced a complicated and premature birth. He deduced that a lack of oxygen during birth leads to the brain injury.
- In 1897, Sigmund Freud disagreed and suggested that the “disorder” could have developed during the brain's development in the womb. He based his position on the fact that children with cerebral palsy often have other problems, such as intellectual impairment, visual disturbances and seizures. He explained that “Difficult birth, in certain cases, is merely a symptom of deeper effects that influence the development of the fetus” (p. 1).
- Up to the 1980's, it was believed that birth complications were the major cause of cerebral palsy. In 1980, an analysis of 35 000 births by the National Institute of Neurological Disorders and Stroke revealed that only 10% of the cases with cerebral palsy were due to complications during birth.

United Cerebral Palsy (2001) differentiated between congenital and acquired cerebral palsy. They stated that there are two sources of congenital cerebral palsy.

Approximately 70% of congenital cerebral palsy is due to brain injuries during intra-uterine life. These brain injuries are present at birth although the condition might only be detected months later. Another 20% of congenital cerebral palsy cases are due to injuries during the birth process. Acquired cerebral palsy is due to brain injuries after birth, and is estimated to account for 10% of incidences of cerebral palsy in the United States. No data were available about the percentages in developing countries.

Congenital cerebral palsy can also be classified according to when the injury occurred in relation to development (United Cerebral Palsy, 2001; Wilston, 1999):

1. From conception to birth: Genetic disorders, maternal disorders, primary fetal abnormalities, infections, cerebral infarcts, inability of the placenta to provide the developing fetus with oxygen and nutrients, lack of growth factors during the intra-uterine life, infection of the mother with German measles or other viral diseases in early pregnancy, bacterial infection of the mother, fetus or infant that directly or indirectly attacks the infant's central nervous system.
2. During the birth process: Birth trauma to normal fetus, any prenatal factors that result in abnormal birth process, prolonged loss of oxygen during the birth process and severe jaundice shortly after birth, premature birth.
3. Up to 28 days after birth: Infections, acute metabolic disorders, RH or A-B-O blood type incompatibility between mother and infant.
4. From 1-24 months after birth: Cerebral infections, head injury (accidental, non-accidental), CNS infections, hemorrhages (subdural, intraventricular).

There are various circumstances that have been identified as predictors of increased risk for congenital cerebral palsy (United Cerebral Palsy, 2001; Wilston, 1999; Cruickshank, 1980):

- Maternal intellectual impairment.
- Fetal malformations.
- Low birth weight (less than 2100g).
- Neonatal seizures.
- Respiratory distress syndrome or delayed first cry (after two minutes).

The causes associated with acquired cerebral palsy have been identified by United Cerebral Palsy (2001) as:

- Brain damage due to brain infections such as bacterial meningitis and viral encephalitis.
- Traumatic brain injuries as a result of car accidents, child abuse, a fall, etc.
- Asphyxia due to poisoning, near-drowning, choking on objects, etc. (Miller & Bachrach, 1995).

Types of Cerebral Palsy

Hadders-Algra (2000) explained that although cerebral palsy can be described generally in terms of groups, there is heterogeneity within each group because of differences in the severity of damage to the affected areas. There is not always a clear distinction between groups either, because it is rare that only an isolated motor area of the brain will be affected. Sherrill (2004) reported that the medical classification of cerebral palsy is presented either according to the body area that is affected (see Table 3) or according to the type of neuromuscular involvement (see Table 4).

Table 3. Classification of cerebral palsy according to the anatomical sites of dysfunction (Topographical classification) (Sherrill, 2004; Poretta, 2000; Steadward, 1998)

Classification	Description
Quadriplegia	Muscular involvement of four extremities, as well as the trunk area. The lower extremities are normally less involved than the upper extremities. Also known as tetraplegia (Sherrill, 2004).
Triplegia	Muscular involvement in three extremities as well as the trunk. Usually two legs and an arm.
Diplegia / Paraplegia	The muscular involvement in the lower extremities is much more than in the upper extremities. Sherrill (2004) prefer the term diplegia above paraplegia.
Hemiplegia	Muscular involvement of one upper extremity and one lower extremity on the same side of the body. The upper extremity is normally more involved.
Monoplegia	Muscular involvement in only one extremity and normally it is an upper extremity.
Double Hemiplegia	More muscular involvement of the upper limbs than the lower limbs.

Table 4. Types of Cerebral palsy according to muscle involvement (Steadward, 1998)

Type	Characteristics
Spastic	Increased muscle tone; tendon reflexes that are easily excitable; exaggerated stretch reflexes.
Athetoid	Low muscle tone; an overflow of involuntary, writhing movements that are purposeless.
Ataxia	Uncoordinated; poor balance; limited spatial awareness; difficulty performing rapid and fine movements.
Tremor	Uncontrolled, strong and regular pendular movements.
Rigid	No stretch reflex; increased muscle tone in both agonist and antagonist muscles result in limited joint movement.
Mixed	A combination of the above types of cerebral palsy.

The most common type of cerebral palsy is the mixed type. The three major types of “single” cerebral palsy - spastic, athetoid and ataxia - are discussed in the following section. Conclusions can be drawn from these definitions about how a person with a mixture of these types might be affected.

Spastic Cerebral Palsy

Incidence. Seventy percent (70 %) of people diagnosed with cerebral palsy are classified as having spastic cerebral palsy (United Cerebral Palsy, 2001). Sherrill (2004) reduced this estimate to 65 % of all people with cerebral palsy.

Area of brain involvement. Damage to the cortical areas of the brain results in spasticity due to exaggerated reflex levels that are normally under voluntary control (Sherrill, Mushett, Jones, 1988). The flexor and internal rotator muscle groups are primarily affected and this results in hypertonicity, which in turn can lead to permanent contractures and bone deformities (Poretta, 2000).

Characteristics. Increased muscle tone (hypertonicity), tendon reflexes that are easily excitable and exaggerated stretch reflexes are primary characteristics of spasticity (Steadward, 1998). Hypertonus usually involves the flexor muscle groups and it can result in weakness in the affected body parts (Sherrill et al., 1988) as well as a gradual decrease in range of motion of the affected limbs (Steadward, 1998). This occurs in different degrees of severity.

When movement is initiated by a person with normal control, the agonist muscle contracts and the antagonist muscle “brakes” the contraction with a degree of muscle tone.

For a person with spasticity, the action of the antagonist muscle does not act as a brake, but rather it reacts against the stretch with a contraction that results in either “blocking” or partially “blocking” the movement. This blocking reaction is caused by the hyperactive stretch reflex (Sherrill, 2004). This stretch reflex can also be initiated by a fast passive movement or pressure on the muscle, which causes the movements of the person with spasticity to appear tense, weak and poorly performed (Levitt, 1964). The release of objects is also very difficult and the ability to make precise movements is affected (Sherrill, 2004; Goodman, 1998).

A person with spasticity in the upper limbs will normally have adducted shoulders. The arm is carried to the midline of the body and the forearm will be flexed and pronated. A hyperflexed wrist with a fist hand can also be present (Poretta, 2000; Sherrill, 2004).

Lower limb spasticity results in hip flexion. The thigh is pulled towards the midline of the body, with flexion at the knee joint and excessive plantar flexion of the ankle. The muscles involved in this body position are tight adductors, tight hamstrings, increased tone in the gastrocnemius and soleus with a shortened achilles tendon (Sherrill, 2004; Poretta, 2000).

Other conditions associated with spastic cerebral palsy. Intellectual impairment, crossed eyes and a low body weight are other conditions that are associated with spastic cerebral palsy (Steadward, 1998). Abnormal posture such as “scissor gait” can occur with spastic cerebral palsy due to the hyperactivity of the stretch reflex (Steadward, 1998; Levitt, 1964).

Treatment: Treatment of spastic cerebral palsy should focus on relaxation, movement education and prevention of contractures (Levitt, 1964).

- Relaxation.

Relaxation can be accomplished by putting the person in a posture where the reflexes are inhibited. The Bobath technique is the most commonly used method (Levitt, 1969; Levitt, 1964). Relaxation drugs can also be used, but it is not always advisable as they also can inhibit voluntary control (Levitt, 1964).

Botulinum toxin (BTX-A) is increasingly used to manage spasticity in individuals with cerebral palsy, but there is no information currently available

about the long-term effects of its use (Gough, Fairhurst & Shortland, 2005). Normal relaxation is never achieved. Learning and practicing motor skills in the relaxed posture is recommended. Surgery to release tendons (such as Achilles tendon), is also conducted to improve posture and movement patterns (Sherrill, 2004).

- Movement education.

Movement education should start with simple movements before movement combinations are tried. The person with hemiplegic spastic cerebral palsy should be encouraged to use the spastic side as much as possible. Psychologically, the person will try to avoid using this side, but should be “forced” through certain activities to make use of it (Levitt, 1964).

- Prevention of contractures.

Passive range of motion training, performed with good rhythm and speed that does not result in spasm, is recommended. Putting a young child into plaster to correct the posture has met with some success. Efforts should be made to prevent a person with flexor spasticity from going into any position that will increase flexion. A person with extensor spasticity should avoid positions of increased extension (Levitt, 1964).

Athetoid Cerebral Palsy

Incidence. Twenty percent (20%) of people diagnosed with cerebral palsy are classified as athetoid, which is also known as dyskinetic cerebral palsy (United Cerebral Palsy, 2001). Sherrill (2004) stated that 25 % of all persons with cerebral palsy are athetoid.

Area of brain involvement. Damage to the basal ganglia of the brain is the primary cause of overflow of motor impulses to the muscles (Poretta, 2000). The basal ganglia is generally responsible for planning and programming the motor commands for muscle tone, posture and locomotion (Goodman, 1998).

Characteristics. As an infant, the child seems to be “floppy”. Little spontaneous movement is noticed and postural tone against gravity is very low (Bobath & Bobath,

1975). Movements of the whole body can be affected in persons with athetoid cerebral palsy. A low muscle tone and slow and uncontrolled movements are present (United Cerebral Palsy, 2001; Steadward, 1998; Sherrill et al., 1988; Levitt, 1964). The involuntary muscles affected include almost all muscle groups except those of the eyes, but are most evident in the face, tongue, neck and arms (Foley, 1969). These uncontrolled movements are often irregular, purposeless and show no pattern. The involuntary movements are provoked by emotional stress and by voluntary movements. In severe cases, involuntary movements can also occur during rest (Levitt, 1964).

Because either hypertonicity or hypotonicity can be present, athetosis is described as either the tension type or the non-tension type (Goodman, 1998). A small degree of tension is normally found in most cases of athetosis. Differentiation is also made between the tension and spastic types, with the hyperactive stretch reflex present in the spastic type.

Athetosis disrupts balance and voluntary movements with weakness in both concentric and eccentric muscle contractions and to a lesser degree isometric muscle contractions (Levitt, 1964). All four limbs usually are affected and often a hollow back is an accompanying characteristic (Poretta, 2000; Steadward, 1998). Due to difficulty with head control, visual pursuits are influenced and this results in difficulties with tracking balls that are thrown towards the person as well as difficulties responding to quick movements. Any movements that require accuracy will be difficult (Poretta, 2000).

Treatment. Treatment focuses mostly on relaxation, movement control and balance.

- Relaxation.

Relaxation can be accomplished by putting the person with athetosis in the most relaxed position possible. Movements can be done out of this position (Levitt, 1964).

- Movement control and balance.

Movements should be started from a relaxed position with single movements attempted before proceeding with combined movements. Coordination and balance exercises are also recommended. Improvements in balance and coordination can improve the gait pattern. The head is generally in an extended

position and excessive head movements can cause balance and coordination difficulties. Training to improve head control is therefore critical. Strengthening exercises are recommended for the weak muscle groups, although exercises should not over-stimulate tension in the muscles (Levitt, 1964). Any balance, coordination and strengthening exercises that result in excessive involuntary movements, should first be broken-down into easier parts (Levitt, 1964).

Ataxia

Incidence. Ten percent (10%) of people diagnosed with cerebral palsy are classified as ataxic (United Cerebral Palsy, 2001; Sherrill et al., 1988).

Area of brain involvement. Ataxia results from damage to the cerebellum. The cerebellum regulates balance and muscle coordination (Poretta, 2000).

Characteristics. Characteristics of ataxia include muscle weakness, poor coordination and balance, a wide base gait and difficulty in performing rapid and fine movements (Sherrill et al., 1988). These characteristics occur in a variety of severities (Goodman, 2004). According to Steadward (1998), the ataxic form of cerebral palsy is marked by a deficient sense of balance and kinesthesia and limited spatial awareness. Levitt (1964) described the ataxic gait as usually tottering, lurching, stumbling and high stepping. The lack of spatial awareness is most noticeable when the hands are used.

Treatment. Treatment of the ataxic person should focus on improving balance, coordination, strengthening of the weak muscle groups as well as an improved gait. Muscle strengthening of the weak muscles groups as well as the postural muscles (the abdominal muscles in particular) are recommended (Levitt, 1964).

The Nervous System and Cerebral Palsy

Cerebral palsy is a disorder that primarily affects the motor functions of the brain. Voluntary and involuntary muscle activity as well as postural reflexes can be compromised. Although the brain is the primary area of injury, the lesions associated with the injury can have an indirect effect on the motor control functions of the spinal cord column and the peripheral nervous system (Cruickshank, 1980). Movement can be seen as a series of postures and these postures are regulated by the relationship between input and

output within the central nervous system. An imbalance between the input and the output can result in the symptoms of neurological dysfunction, such as cerebral palsy (Cruickshank, 1980).

The Levels of the Central Nervous System

Movement performance operates under the integrated control of four levels of the central nervous system (MacDonald & Chance, 1964).

Spinal level. The spinal cord is the lowest level of the central nervous system, providing the connections for a number of reflexes. Afferent stimuli enter a segment of the cord and stimulate motor neurons exiting from that segment on the same side or the opposite side. These are called homolateral or contralateral reflexes. Longitudinal reflexes can also occur. This happens when afferent stimuli travel higher or lower in the spinal cord before stimulating a motor neuron. Reflexes such as the flexor withdrawal reflex, the extensor thrust, and the cross extensor reflex are mediated at this level. As the normal child develops, these spinal reflexes come under the control of the higher centers in the central nervous system, but in some cases of cerebral palsy, higher levels of control never develop and the reflexes stay active when the stimuli occur (MacDonald & Chance, 1964).

Pontine level: The second level is the brain stem level. Changes in head position result in afferent stimuli from the labyrinths in the inner ear and the muscles from the neck. Afferent stimuli synapse with the motor neurons in the brain stem and result in postural reactions. The asymmetric tonic neck reflex is an example of this. This reflex is seen in infants without cerebral palsy, and under normal circumstances, is progressively brought under control from a higher level. However, in some kinds of cerebral palsy, control of the head and postural position from higher levels does not develop and the reflex remains (MacDonald & Chance, 1964).

Midbrain level. This area reacts to tactile stimuli from the surface areas of the body. Tactile stimuli result in modifications of motor responses during normal developmental stages of motor function as children progress from rolling over to standing. Cortical control at the next level of the central nervous system inhibits these reflexes as the normal child develops. With cerebral palsy, cortical control might not develop and these reflexes can continue to affect movement in uncontrolled ways (MacDonald & Chance, 1964).

Cortical Level. This is the highest level of motor control in the body. It is the ultimate control center for the nervous system. A nervous system that is intact and mature has control over voluntary motor activities and can modify performance as needed (MacDonald & Chance, 1964). A person with cerebral palsy will not have full cortical control of his/her motor performance.

Brain Involvement in Cerebral Palsy

The three major areas of the brain that may be involved in cerebral palsy are the cerebrum, the cerebellum and the basal ganglia.

Cerebrum. This part of the brain includes the cerebral cortex, which performs the functions of perceiving and interpreting sensory information, making conscious decisions and controlling voluntary movements (Latash, 1998). The cerebrum consists of two hemispheres divided by a longitudinal fissure. These two hemispheres differ in their function. The left hemisphere controls the movement on the right side of the body and the right hemisphere the movement on the left side of the body. Each cerebral hemisphere is divided into lobes which are named after the bones of the skull that protect them. Because the lobes have different functions, injuries to different lobes will impact differently on motor performance (see Table 5).

Table 5. The roles of the different lobes of the cerebrum in terms of functions (Seeley, Stephens & Tate, 1996)

Lobes	Functions
Frontal	Voluntary motor control; Motivation, aggression and mood. Olfactory reception (smell).
Parietal	Principal center for reception and evaluation of most sensory information such as touch, pain, temperature, balance and taste.
Occipital	Principal centre for the reception and integration of visual input.
Temporal	Evaluates olfactory (smell) and auditory (hearing) input; Plays an important role in memory; Associated with abstract thought and judgment.

A significant area for the study of motor control in cerebral palsy is the primary motor cortex that is located in the posterior portion of the frontal lobe. Stimuli initiated in this area normally control voluntary movements of the skeletal muscles (Seeley et al., 1996). Damage to the primary motor area can induce complete or partial paralysis. This paralysis includes uncontrolled spasms and spasticity (an increased level of muscle contraction) (Latash, 1998).

The other important area for the study of cerebral palsy is the premotor area of the frontal lobe. The frontal lobe is responsible for the decisions and the capacity to plan movements and movement sequences (Seeley et al., 1996). Motor functions are organized in the premotor area before motor commands are initiated by the primary motor cortex. More complex movements are controlled and initiated in the premotor area and a greater magnitude of stimulation is needed to initiate movement performance. The premotor area has two major zones, the premotor cortex (lateral surface of the hemisphere) and the supplementary motor area (superior and medial areas of the hemisphere). Damage to the premotor cortex affects the ability to use external cues to control movements (Latash, 1998). The fact that the supplementary motor area has a full “map” of the body, indicates that if damage occurs to this area of the brain, the ability to construct movements based on internal memory becomes impaired (Latash, 1998).

The Path of Stimuli to and from the Motor Cortex. Stimuli come from the spinal cord, basal ganglia and cerebellum to the thalamus. The thalamus distributes stimuli to the primary motor area, pre-motor area and the supplementary motor area. When decisions are made regarding the commands (output) sent from the motor cortex, efferent signals are sent to the basal ganglia, the cerebellum, reticular formation and the spinal cord and movement follows (Latash, 1998). Fine control over grasping movements requires the pyramidal pathways (Shumway-Cook & Woollacott, 2001). The pyramidal pathways originate in the sensorimotor areas of the cerebral cortex and descend through the brainstem to the spinal cord and is also known as the corticospinal track (Shumway-Cook & Woollacott, 2001).

The Cerebellum. The cerebellum consists of nuclei and nerve tracts. The major function of the cerebellum is that of a comparator. It is involved in balance, maintenance of muscle tone and coordination of fine motor movements (Seeley et al., 1996). The comparator function is fulfilled in the following way (Seeley et al., 1996):

- To initiate voluntary movements, the primary motor cortex sends action potentials (commands) into the spinal cord. At the same time, collateral branches are sent to the cerebellum carrying information regarding the intended movement.
- Feedback from the proprioceptors reaches the cerebellum to provide the cerebellum with information about the positions of the body and how it is moving.
- In order to perform smooth and coordinated movements, the cerebellum compares the intended movement potentials from the primary motor cortex, with the feedback about the actual movements. If discrepancies are found, the cerebellum sends action potentials (commands) to the motor neurons in the motor cortex and spinal column to adjust or correct the movement to become the intended movement.

Disorders of the cerebellum result in clumsy movements and decrease in muscle tone (Seeley et al., 1996).

Basal ganglia. The basal ganglia are a group of functionally related nuclei, with part of the nuclei located deep within the cerebrum and the other part in the midbrain. The basal ganglia play a role in inhibiting muscular activity, decreasing muscle tone, coordinating motor movements and generally contributing to the control of posture (Latash, 1998). Disorders of the basal ganglia result in disruptive increases in muscle tone and exaggerated, uncontrolled movements (Seeley et al., 1996).

Reflexes and Cerebral Palsy

“A reflex is an involuntary reaction in response to a stimulus applied to the periphery and transmitted to the central nervous system” (Seeley et al., 1996, p. 204). Latash (1998) defined a muscle reflex as “a muscle contraction induced by an external stimulus that cannot be changed by pure thinking, that is, by a volitional act that is not accompanied by another muscle contraction” (p. 64). Reflexes operate on a neural pathway. The reflex arc is a basic functional unit of the nervous system and the smallest, simplest pathway capable of receiving a stimulus and responding to it. Most reflexes involve the spinal cord or brainstem and not the higher brain centers. Reflexes allow a

person to react to stimuli unconsciously, without thought and are critical when time is limited (Seeley et al., 1996).

The developing child depends on reflexes to help maintain posture, muscle tone and to initiate coordinated movements (Melyn & Grossman, 1976). Profound changes take place during a child's development, especially during the first 18 months. The first movements the child makes are reflex movements. As the child develops, the movements become more refined and come under voluntary control. This is why at certain stages of a child's development, it is expected that a child will be able to control certain fundamental movements (Bobath & Bobath, 1975).

For the child with cerebral palsy, a lesion in the cerebral cortex results in the persistence of some reflex movements which interferes with the development of the voluntary control of movement (Melyn & Grossman, 1976). Some of the reflexes that persist in persons with cerebral palsy are described briefly in Table 6.

Cycling for Persons with Cerebral Palsy

The regulations of the International Cycling Union apply for all competitions, except for some additional rules provided by the International Paralympic Committee. Among these rules are those used for the classification of cyclists with cerebral palsy. Classification of cyclists is the placing of cyclists into categories based on an assessment of their functional abilities to meet the movement challenges of cycling.

Classification

Classification criteria for individuals with cerebral palsy are guided by the Cerebral Palsy – International Sport and Recreation Association (CP-ISRA). The Paralympic Games of 1984 played a central role in refining the classification system for athletes competing in disability sport (Williamson, 1997). Classification allows the athlete to compete against other athletes with similar abilities and the deciding factor for classification is the extent and nature of the disability (Sherrill, 1999; Davis & Ferrara, 1996).

Table 6. Common reflexes that may persist in persons with cerebral palsy (Melyn & Grossman, 1976, pp. 83-89; Goodman, 1998)

Reflex	Brief description
Stretch Reflex	When pressure is put on the muscle tendon, the tendon stretches. The stretch results in an impulse to the spinal cord, which produces a contraction of the muscle and therefore extension (patella tendon tap, knee extension). The stretch reflex appears in any person and it functions to prevent injury. <i>In a person with cerebral palsy (ataxia) the stretch reflex is hyperactive and results in unwanted reflex activity (Goodman, 1998).</i>
Symmetrical Tonic Neck Reflex	a. If the head is tilted back when the infant is in the prone position, the arms will extend backwards and the legs will flex at hips and knees. b. If the head is flexed forward when the infant is in the prone position, the arms will flex and the legs will extend. <i>This reflex is normally present until the age of six months, but persists in some individuals with cerebral palsy.</i>
Asymmetrical Tonic Neck Reflex	If the head is tilted to the left side when the infant is in the supine position, the left arm will abduct and extend, and the right leg will extend. Flexion of the contralateral limbs will occur. The opposite reaction will follow if the head is tilted to the right side. <i>This reflex disappears normally at the age of 7 months, but persists in some individuals with cerebral palsy</i>
Righting Reflex	If the head is rotated to one side, it will lead the shoulders, trunk and pelvis to rotate to the same side. <i>As the infant grows, this reflex leads to the ability to correctly orient the head and neck relative to the body, a capacity that may not develop in an individual with cerebral palsy.</i>
Positive Supporting Reaction	When the infant is in the vertical position, held under the arms, feet in the air and the head is up, the feet will make automatic stepping movements. As the foot touches something, the foot will be push off the area it touched and the next foot will follow (stepping down). <i>This becomes a voluntary action as the child grows, but an individual with cerebral palsy may never get full control of this reflex.</i>
Lengthening Reaction	A stretched muscle results in an increase in muscle tone and some resistance to continued stretching. If a certain point is reached, the muscle “releases” to allow further stretching under decreased tension. <i>This reflex is more prominent in older children and adults, but individuals with cerebral palsy may not possess this capacity.</i>
Parachute Reaction	A child held prone and brought closer to a surface, extends the arms and spreads his/her fingers apart. <i>This reflex is present from 9-11 months and persists throughout life.</i>
Plantar Reflex	From birth to 15 months, noxious stimulus to the lateral border of the foot will result in extension and fanning of the toes, with dorsiflexion of the great toe. The foot may be withdrawn. <i>Noxious stimulus to the lateral border of the foot in an adult result in symmetrical flexion of the toes and foot.</i>
Grasp Reflex	Tactile stimuli to the soles or palms of the infant results in an immediate response of flexion of the toes or fingers respectively. <i>This reflex becomes more voluntary as the child develops.</i>

Medical classification categorizes the athlete depending on the nature of his/her disability (Davis & Ferrara, 1996). The degree of the cerebral palsy is determined by a team of classifiers consisting of physicians or therapists and a number is allocated to the individual according to the functional ability of the individual. A description of the general categories of cerebral palsy in terms of impact on movement is presented in Table 7. After the medical classification, the individual with cerebral palsy is then classified according to the sport, the functional system. This allows an individual to compete against other individuals who show the same functional abilities in that specific sport.

Table 7. General classification in cerebral palsy (from Winnick, 1990)

Class	Short Description
1	Uses a motorized wheelchair. Severe spasticity and/or athetosis. Poor functional range of motion and strength in all extremities; poor trunk control.
2	Might be able to propel wheelchair on level ground. Severe to moderate spasticity and/or quadriplegic athetosis. Poor functional strength in all extremities with poor trunk control. Can be classified as II (lower) or II (upper) dependable on which extremities are most functional.
3	Can propel wheelchair independently. Might walk short distance with assistive devices. Moderate quadriplegic or severe hemiplegia. Fair to normal strength in one upper extremity.
4	Wheelchair is used for sport, but assistive devices for distance walking. Moderate to severe diplegia with good functional strength and minimal control problems in the upper extremities and torso.
5	No wheelchair is necessary, but might use assistive devices. Moderate to severe diplegia or hemiplegia with moderate to severe involvement in one or both legs. Good functional strength with good balance when assistive devices are used.
6	Can ambulate and the gait seems more functional when running than walking. Moderate to severe quadriplegia (spastic/athetoid/ataxic) with fluctuations in muscle tone that produce involuntary movements in the trunk and both sets of extremities. Greater upper limb involvement when spasticity/athetosis is present.
7	Walks and runs without assistive devices. Moderate to minimal spastic hemiplegia. Good functional ability on non-affected side.
8	Runs and jumps with little to no limp. Minimal hemiplegia, monoplegia, diplegia or quadriplegia. May have minimal coordination problems, but good balance.

Williamson (1997) explained that there are two phases in determining an individual's sport classification. First, the strength, range of motion, motor coordination and balance needed to perform in the sport must be assessed. Second, the individual is evaluated when performing his/her sport actions, e.g. the cycling action. Classification for a specific sport is done by movement specialists in conjunction with a technical classifier. A technical classifier has knowledge about the sport as well as the disability and knows

what factors will have an influence on performance of the specific sport. A prospective athlete is evaluated for his/her movement potential in that sport, then assigned a sport-specific classification, for example, a classification for cycling consists of 4 different categories for cerebral palsy cyclists (see Table 8).

Division 1 is the most severe and Division 4 the least severe. Division 1 and 2 compete on tricycles due to problems with balance and coordination and Division 3 and 4 cyclists compete on bicycles.

Table 8. Cycling classification for individuals with cerebral palsy (IPC Handbook, n.d.)

Division	Short Description	Cycle	Road Race	Track Race
1	CP-ISRA classes 1-4.	Tricycle	Minimum ½ Hour or 15 km Maximum 30 km	No
2	CP-ISRA classes 5 & 6 (Cyclist can choose either Division 2 or 3)	Tricycle	Minimum ½ Hour or 15 km Maximum 30 km	No
3	CP-ISRA classes 5 & 6	Bicycle	Minimum 1 hr or 35 km Maximum 70 km	1km Standing Start & 3000 m Individual Pursuit
4	CP-ISRA classes 7 & 8	Bicycle	Minimum 1 hr or 35 km Maximum 70 km	1km Standing Start & 3000 m Individual Pursuit

Cycling Patterns and Cerebral Palsy

Not all persons with cerebral palsy manage to ride a bicycle or tricycle. In a study by Parker, Carriere, Hebestreit and Bar-Or (1992), it was found that not all individuals with cerebral palsy who are ambulatory (with and without assistive devices) have the ability to cycle. This can be attributed to extraordinary problems with coordination and balance needed for cycling, even on a tricycle. The study was conducted on 46 subjects with spastic cerebral palsy (quadriplegic, hemiplegic, diplegic) and their ages varied between 6- 14 years. A cycle ergometer with extra strapping for the hands and feet was used for the test. It was reported in this study that the smoothness needed for forward pedaling was severely compromised with increased cadence among some cyclists with cerebral palsy. The authors indicated that the co-contraction of the agonist and antagonist muscles could be the reason for this inability to achieve and maintain a smooth cycling action.

This may be why some individuals with cerebral palsy cycle with a piston-like movement pattern. Kaplan (1995) described it as a fast downward push with the quadriceps with a collapse into flexion and a noticeably prolonged transition between flexion and extension at the top and bottom of the cycling action.

Kaplan (1995) completed a study in which he compared the time the crank of the bicycle spent in each quadrant for 15 spastic diplegic children with cerebral palsy to that of their peers (n= 15) without cerebral palsy. A smooth cycle action would result in equal time in each quadrant. This study confirmed the observation that children with cerebral palsy push down and flex up faster than children without cerebral palsy, but the transition time between their push and pull was much slower. He also monitored muscle activation of the gastrocnemius, tibialis anterior, rectus femoris and hamstring muscle groups. He found that children without cerebral palsy had co-contraction of the tibialis anterior and the gastrocnemius for 29% of the cycle time and co-contraction between the hamstring and rectus femoris muscle groups for 13% of the time. In contrast, the co-contraction for children with cerebral palsy increased to 49% of the time between the tibialis anterior and the gastrocnemius and 53% of the time between the hamstring and rectus femoris.

Physical Aspects of Cycling for Persons with Cerebral Palsy

For athletes with physical disabilities, the same or similar physical challenges must be met as for athletes without physical disabilities who participate in the same events (Goodman, 1998). To improve performance, the cyclist with cerebral palsy needs to consider the training methods pursued by cyclists without cerebral palsy and try to apply them. Some modifications may have to be made to the training programme based on the nature of the cyclist's particular type of cerebral palsy and/or the functional ability of the individual.

The most important thing when considering overall guidelines or universal rules of training for the athlete with cerebral palsy (CP) is to realize there are many more similarities among all athletes, even those with certain physical disabilities, than dissimilarities between individuals with handicapping conditions. (Morris, 1988. p.47)

Due to the wide range of abilities among persons with cerebral palsy, it is important to customise and manage the training for each person according to their strengths and

weaknesses. The fact that cerebral palsy is a neuromuscular dysfunction resulting from an injury to the motor control areas of the brain, implies that different motor functions will be affected in different individuals in different ways. The specific impact of cerebral palsy on movement should determine what types of training and what modifications should be made for each individual.

The treatment of persons with cerebral palsy focuses on managing the collection of impairments resulting from the brain damage (Goldsten, 2004). These impairments will have a direct impact on the physical fitness status of persons with cerebral palsy. Knowledge about physical fitness of individuals with cerebral palsy can assist in determining the effects of therapeutic interventions as well as give an indication of the true functional ability of the individual (Parker et al., 1992).

Compton, Eisenman & Henderson (1989) stated that the term “physical fitness” implies that a specified level of function has been achieved. If a person wants to become fit, a certain level of achievement for each fitness component needs to be developed. For the current study, physical fitness is defined as the ability to carry out tasks with vigor and alertness, without undue fatigue, to enable the cyclist to achieve the desired performances. It is important to consider the effect of cerebral palsy on some of the common variables associated with fitness in sport, when either evaluating a cyclist with cerebral palsy or when training interventions are recommended. The relative importance of the different fitness components will also vary among individuals with cerebral palsy, and must be considered during planning and implementing training programmes.

Anthropometry

Anthropometry is a series of systematic measurement techniques for measuring the size, weight and body proportions of the human body. It expresses the human body proportions quantitatively and involves the use of carefully defined body landmarks (Pollock, Garzarella & Graves, 1995). Anthropometry includes body physique types, body fat percentage, body mass index as well as proportions of body lengths and circumferences (Malina, 1995).

The general importance of anthropometry is that it supports the determination of percent body fat for individual health risk factors (AAHPERD, 1980). The importance of body physique and body composition for competitive sport is well known.

Anthropometrical evaluations are used for talent identification in sport, which indicates how important certain body physique elements are for excellence in a certain sport. Woolford (1993) observed that sport performance generally declines when fatness increases. His explanation was that an excess of fat leads to an earlier onset of fatigue because fat is a non-contributing load, offering no assistance to the mechanics of movement.

Anthropometry and Cycling

Body mass is not as important for cycling as is lean body mass. Lean body mass, is calculated by subtracting the fat mass from the body mass. If a cyclist carries too much body fat, it is a disadvantage as the fat is not a contributing factor to the power produced. In contrast, the role of the LBM, especially in the legs and gluteus, is to provide the power output. On flat or down hill events, the negative effect of a high fat mass is not as great, as when a cyclist need to carry his/her weight uphill. Fat percentages for male cyclists range from 8 to 12% and for female cyclists from 10 to 15% (Burke, 1995). In another study, the percentage fat in female cyclists range from 7 to 15% body fat, with the range of the sum of seven skinfolds in the Australian female cycling team from 38 to 51 mm (Martin, Mclean, Trewin, Lee, Victor & Hahn, 2001).

Other variables related to body composition can have an influence on cycling performance. Armstrong & Carmichael (2000) stated that power to weight ratio is one of the most important contributing factors in road cycling where terrain can include flat and hilly portions. Coyle et al. (1991) disagreed in his study and found a negative correlation between time to ride a 40km time trial and absolute power output ($r=-0.88$; $p<0.001$), indicating that absolute power output is a good indicator of time trial ability. Absolute power output is an indicator of time trial ability if the terrain is flat such as the laboratory time trial in the study of Coyle et al. (1991). Morphological characteristics such as body mass, height, body surface, frontal surface area and body mass index (BMI), may have an impact on performance in different terrains. Cyclists with different body shapes may excel in different components of cycling, but research shows that body size only accounts for 10-20% of cycling time and many other variables play important roles in performance (Swain, 1996). Lucia et al. (2001) stated that the all-round cyclist tends to take the shape of a time trial specialist (see Table 9).

Table 9. Anthropometrical characteristics of elite cyclists with special expertise in either climbing or flat time trials (Lucia, Hoyos, & Chicharro, 2001)

Type of cyclist	Weight	Height	BMI	Fat percentage
Climbing	60-66kg	175-180cm	19-20	8-10%
Time Trial	70-75kg	180-185 cm	± 22	8-10%

The heavier and taller cyclist tends to perform better on flat terrains or time trials while the shorter and lighter cyclist will be the climber (Lucia et al., 2001; Swain, 1996). When cycling on flat terrain, the most important factor in slowing a cyclist down is wind resistance. A larger cyclist has a bigger surface area than a smaller cyclist and the bigger the surface area, the greater the demand for energy to perform. But the best time trial cyclists tend to be relatively large because larger cyclists tend to have a greater muscle mass to body mass ratio, and it appears that this greater power supply outweighs the disadvantage in terms of wind resistance (Burke, 1995). Cyclists with a larger frontal surface area have a greater absolute energy cost on a flat terrain than cyclists with a smaller frontal surface area, but the energy cost relative to their weight is less for the larger cyclist. Oxygen cost measures will be greater (Wilston, 1999), but when measurement is in ml/kg/min, the cost will be less. This example supports the calculation of oxygen cost as a percentage of maximal oxygen uptake (Swain, 1996).

Burke (1995) reported that uphill cycling seems to benefit the smaller cyclist. This is not because of the smaller surface size but because the smaller cyclist has a larger relative capacity to deliver oxygen to the working muscles. Therefore, it is not the body size that really matters, but rather the aerobic capacity. If a larger cyclist can develop the same relative capacity between oxygen delivery and body size, the larger cyclist would be able to beat the smaller cyclist to the top (Burke, 1995). A long, sustained hill will be the ideal breakaway area for a cyclist with a small frontal surface area. The power-to-weight ratio is very important in a long sustained hill, because gravity will favor the smaller cyclist (Swain, 1996).

At the end of a stage where sprinting is important, the larger cyclist will have the benefit. If aerobic endurance is out of consideration, the ATP-PCr system is responsible for the power during a short sprint and this brings the bigger powerful riders in consideration (Swain, 1996).

An increase in non-functional mass can have a negative impact on performance. Additional fat mass contributes to the energy cost of starting, accelerating and rolling resistance, and is associated with an increase in the frontal surface area of the cyclist (Craig & Norton, 2001). Research on anthropometric parameters has shown that success in shorter distances is associated with cyclists who have heavier and stronger (mesomorphic) bodies, and that success in time trials and pursuits are associated with more ectomorphic cyclists with longer leg-height ratios (Craig & Norton, 2001).

Anthropometry and Cerebral Palsy

Modifications of standard body composition measurements may be necessary based on the individual's ability, ambulation mode, degree of muscle spasticity and susceptibility to fatigue (Steadward, 1998). For example for the hemiplegic individual, the comparison between the two sides can be important in determining body type. In Project Unique, Winnick and Short (1985) found that the skinfold measurements of children with cerebral palsy were similar to their able-bodied peers. Of importance when doing anthropometrical evaluations with persons with cerebral palsy is to compare the individual to him or herself.

Flexibility

Winnick and Short (1985) defined flexibility as “ the component of physical fitness which refers to the range of motion around one or a sequence of joints, for example, the degree of stiffness or looseness of a joint” (p. 41). Therefore, flexibility is joint specific and optimal ranges of motion are sport-specific. The optimal range of motion for a certain joint will depend on the physical demands the specific sport puts on that joint for a certain range of motion that needs to be achieved. Gambetta (1999) noted that “flexibility is not a static component in sport but a dynamic controlling quality that allows the joint to go through as large a range of motion as can be controlled” (pp. 12-13).

Flexibility is affected by the type of joint. The bony structures, ligaments and muscle attachments play a role in the degree of flexibility of a joint (Bompa, 1999). Stopka (1996) identified flexibility as a factor that can play a role in injury prevention. A positive correlation between muscle tightness, muscle strains and tendonitis is found (Calder & Sayers, 1992).

Flexibility and Cycling

Limited range of motion or flexibility of the hip, knee and ankle joints can be seen as a risk factor for injuries in cycling (Brown, 2002). Cycling is a sport with repetitive muscle contractions and high repetitions of the same muscle actions can result in shortened muscles (Friel, 2003). Excessive pedaling can result in muscles losing their elasticity, especially the hamstring muscles (Friel, 2003). These tight hamstring muscles can result in tightness in the lower back and a whole sequence of tightness in the body can follow. The long hours spent in the same body position during training can result in a loss of elasticity in some muscles as well as the range of motion around certain joints that can limit the ability to generate power on the pedals during the cycling action (Armstrong & Carmichael, 2000). Shortened muscles can result in different muscle contraction patterns and the end result can be an overuse injury, inflammation, tendonitis etc. The shortened hamstring muscle can prevent the leg from fully extending and the power produced by the leg is less (Friel, 2003).

Flexibility and Cerebral Palsy

The person with a physical disability generally has less flexibility than their able-bodied peers (Winnick, 1990). The development and maintenance of flexibility is a primary objective in persons with cerebral palsy, although a good range of motion is not always possible. The lack of adequate flexibility limits motor performance (Winnick & Short, 1985). Krivickas (2003) stated that “spasticity decreases flexibility through hyperactivity of the muscle spindle reflex and of supra-segmental reflexes resulting in a reduced active range of motion” (p. 31).

Bompa (1999) observed that flexibility is often limited if the coordination between the contraction of the agonist muscle and the relaxation of the antagonist muscle is poor. In cerebral palsy, co-contraction of agonist and antagonist muscles is common and therefore flexibility can be limited. Engsberg et al., (2000) found that children with cerebral palsy had a smaller dorsi/plantarflexion range of motion than their able-bodied peers due to tight plantarflexion muscles. Permanent contractions (spasticity) produce shortened muscles and therefore contribute to a lack of flexibility. For example, any sudden stretch in persons with spastic cerebral palsy might trigger a strong muscle

contraction (the stretch reflex) (Rusling, 1988). This results in a negative impact on flexibility.

Little research has been done on the effect of flexibility training on neuromuscular diseases, but it is widely included as an important focus for therapeutic interventions to decrease contractures (Krivickas, 2003). In spastic cerebral palsy, the spastic muscle will be tight and the antagonistic muscle will be over-stretched. Flexibility training for the tight muscle is highly recommended to improve muscle function and balance (Steadward, 1998). It is important to highlight the importance of flexibility training with any strength training programme especially for individuals with cerebral palsy (Goodman, 1998).

Strength

Strength is the ability of a group of muscles to exert maximal effort in a single contraction (Horvat, 1990). Force is produced when this single contraction is applied to matter so that it changes the state of rest or motion of the matter (Knuttgen, 1995). Bompa (1999) defined strength as “the neuromuscular capability to overcome external and internal resistance” (p. 320). Muscle contractions can be concentric, eccentric or isometric. Concentric muscle contraction is where the muscle shortens when it contracts. Eccentric muscle contraction is the lengthening of the muscle while exerting force. Isometric contraction is when there is no shortening or lengthening of the muscle when it contracts (Knuttgen, 1995; Siff, 1993).

Zatzyorski (cited in Bompa, 1999) stated that strength is a function of the interaction of three factors: intermuscular coordination, intramuscular coordination and the force with which the muscle reacts to a nervous impulse.

- Intermuscular coordination: The interaction of various muscular groups during performance.
- Intramuscular coordination: The ability to recruit the neuromuscular units in a muscle to simultaneously take part in the task.
- Force with which the muscle reacts to nervous impulse: “Only 30% of the muscle potential is used when a stimulus reaches the muscle. It should therefore

be trained under higher demand to enable the muscle to use a greater amount of its potential” (p. 320).

To increase strength, neurological adaptations and muscle hypertrophy need to take place (Dompier, 2001). However, strength training programmes must be carefully designed. Muscle balance is an important component in strength and a lack of muscle balance can lead to injuries or postural deviations. Muscle balance is the ratio between the agonist and antagonist in a movement or the relationship between the concentric and eccentric forces of the same muscle group (Siff, 1993).

Strength and Cycling

Successful cycling requires a combination of muscular strength, power and endurance (Burke, 2002). The training programme for a cyclist during off-season is normally many hours on the bicycle at a relatively slow pace. This type of training decreases the cyclist’s short-term explosive power (Van Diemen & Bastiaans, 2002). To compensate for the potential loss in explosive power, off-season resistance training is highly recommended for cyclists (Friel, 2003; Burke, 2002; Van Diemen & Bastiaans, 2002; Hess, 1996; Burke, 1983). It improves the muscular strength and endurance of not only the muscles used during cycling, but also the supportive muscle groups. Burke (1983) commented that a cyclist that wants to reach his full potential needs to make a resistance training programme part of the training plan.

Resistance training not only increases power output but also may enhance endurance capabilities by changing the muscle-fiber recruitment pattern. Due to the increase in power of the slow-twitch muscle fibers, less fast-twitch muscle fibres are necessary at a certain level of performance (Friel, 2003; Van Diemen & Bastiaans, 2002). Strength training programmes can result in increased leg strength and a longer time to exhaustion during cycling, without increasing maximal oxygen consumption. A longer time to exhaustion means that a cyclist can ride at a higher intensity before fatigue sets in (Hickson, Dvorak, Gorostiaga, Kurowski & Foster, 1988). Hickson et al. (1988) found that although $VO_2\text{max}$ did not improve after resistance training with trained cyclists, time to exhaustion did improve by 11 %. Strength training has been shown to improve lactate threshold (Burke, 2002). This might be explained by the recruitment of fewer fast-twitch

muscle fibers due to the increase in power of the slow-twitch muscle fibres after strength training (Friel, 2003).

It was found that some cyclists are hesitant to start with a resistance training programme because of the potential weight increase (Hickson et al., 1988). Increased weight means an increase in power will be necessary to achieve the same performances. Hickson et al. (1988) found no increase in thigh girth after a 10 week, 3 days/wk strength training programme, but there was an increase in leg strength. Friel (2003) reminded coaches that it is important to avoid increasing the size and shape of the muscles by using a hypertrophy programme, and rather focus on improving the use of the existing muscle mass by improving recruitment patterns. Track cyclists need to spend more time on developing strength and power in the gymnasium due to the high intensity and power requirements of the track races than the road races (Van Diemen & Bastiaans, 2002).

It is also important to focus on the muscles necessary for the cycling action (Friel, 2003; Van Diemen & Bastiaans, 2002). Strength training programmes for cyclists should be periodised along with an endurance training programme (Friel, 2003; Burke, 2002; Van Diemen & Bastiaans, 2002). The strength training programme should follow the sequence of anatomical adaptation, maximum strength, power-endurance and muscular-endurance in the build up to the season for endurance cyclists (Friel, 2003). Maintenance of strength and power during the season should be done by either doing strength training on the bike or some form of resistance exercises in the gymnasium (Friel, 2003). Strength training of the abdominal, upper body and back muscles should be maintained throughout the season to enable the cyclist to maintain a proper cycling position without muscle strain (Hess, 1996; Burke, 1983). Muscular endurance, a component of strength training, is important to enable the cyclist to repeatedly turn a relatively high gear at a relatively high cadence (Friel, 2003).

Strength Training for Cyclists

Strength training in the gymnasium should be specific to the cyclist's needs. A periodised programme for strength training can be followed (Burke, 2002). Friel (2003) defined strength in cycling as the ability to overcome resistance, which is very important for climbing and riding into the wind. He stated that strength can be developed in the weight room, especially during the off-season. Although training in a weight room can be

maintained throughout the season, hill work and speed intervals on the bike should replace some weight training sessions in order to make training more specific to cycling.

Strength and Cerebral Palsy

Muscle weakness and spasticity are the two main characteristics of the motor impairment for persons with cerebral palsy (Ross & Engsberg, 2002; Engsberg et al., 2000). Children with cerebral palsy have been found to have weak skeletal muscles, but this weakness is non-progressive (Bar-Or, 1996).

Spasticity is defined in many ways such as muscle hypertonia or a hyper-active deep-tendon reflex. Most recently, it has been defined as a velocity-dependent resistance to passive stretch (Engsberg et al., 2000; Fowler, Nwigwe & Wong Ho, 2000). Spasticity can therefore be assessed by measuring resistance to passive motion.

In their research study (Ross & Engsberg, 2002), 60 spastic diplegic children (mean age = 12 years) were compared to 50 individuals (mean age = 12 years) to determine the relationship between spasticity and strength in individuals with spastic diplegia. Ross & Engsberg (2002) investigated the following three contradictory assumptions:

- A spastic muscle is a strong muscle.
- A spastic muscle is a weak muscle and the weakness depends upon the amount of spasticity or damage to the pyramidal tracts that is situated in the medulla.
- No relation between spasticity and strength but that muscles of persons with cerebral palsy are weak and no more strength can be produced.

The results of the Ross & Engsberg (2002) study were as follows:

- Spasticity/strength in same muscle group – No significant correlation between knee flexor spasticity and knee flexor strength was found as well as between ankle plantar strength and spasticity.
- Spasticity/strength relation of opposing muscle groups at a joint – No significant correlation between knee flexor spasticity and knee extensor strength as well as plantar flexor spasticity and dorsiflexor strength.

- Spasticity/strength cerebral palsy group vs. without cerebral palsy – Individuals with cerebral palsy had greater spasticity at knee and ankle joints as well as greater weakness in the muscles at both joints for both maximum torque as well as work done.

In summary, Ross and Engsberg (2002) established that spasticity was not related to strength, and spasticity is not the cause of muscle weakness in persons with cerebral palsy. The muscle weakness that was found can be the prevailing impairment in individuals with cerebral palsy and not the spasticity, therefore strength training is recommended.

Research has been completed that explored the interaction of strength training and spasticity (Sterr & Freivogel, 2004; Fowler et al., 2000; Engsberg et al., 2000). Sterr & Freivogel (2004) explained that most physical therapists follow the Bobath concept of neural development treatment. The central focus of the Bobath approach is to reduce the muscle tone before any normal movement patterns can be introduced during interventions. The concept is based on the belief that increased muscle tone leads to the observed motor deficits in persons with cerebral palsy. Training-based interventions performed under increased muscle tone will have a negative effect on spasticity and therefore motor performance. Interventions focus on prevention of abnormal postures and excessive co-contraction (Fowler et al., 2001).

However, recent research is in conflict with the Bobath approach (Sterr & Freivogel, 2004; Ross & Engsberg, 2002; Fowler et al., 2000; Engsberg et al., 2000). All these studies show that neither strength training nor movement training necessarily increase spasticity. Sterr & Freivogel (2004) examined upper limb resistance training to determine if there was any increase in spasticity and decrease in function. For persons with lower-to-moderate spasticity, improved motor control and a decrease in spasticity was noted following movement training.

Muscle imbalances will be found in persons with cerebral palsy due to the spasticity in the flexor groups and the lengthening of the extensor groups. Individuals with hemiplegic cerebral palsy will also have muscle imbalances between the affected and non-affected sides. Research completed by Engsberg (2000) found that greater spasticity exists in the hip adductors in individuals with cerebral palsy than in their able-bodied peers.

Research on ankle spasticity by Engsberg, Ross, Olree and Park (2000) documented that persons with spastic diplegia had significantly more spasticity in the plantar flexors than persons without cerebral palsy. The tests for spasticity were conducted on an Isokinetic KinCom dynamometer. The child was instructed to relax while the machine passively moves the ankle or knee joint through the range of motion. The machine torque required to move the ankle or knee through the range of motion was recorded (Engsberg et al., 2000). The faster the speed during the test, the greater the resistive torque for the plantar flexors for the persons with cerebral palsy, while those without cerebral palsy showed no difference in resistive torque with increase in speed. This is an indication that spasticity is velocity dependent. The strength in both the plantar- and dorsiflexors were also less than the group without cerebral palsy.

Isokinetic testing was found to be a reliable test for strength testing of the muscles of the knee joint (Ayalon, Ben-Sira, Hutzler & Gilad, 2000). The best reliability was found using testing at 90 degrees/sec by Ayalon et al. (2000). They recommended that strength testing should be done individually and not compared to norms, but to the individual's previous test results. Isokinetic testing at 30 degrees/s was found by Van den Berg-Emos et al. (1996) to be the most reliable isokinetic testing speed, stating that at faster speed coordination between agonist and antagonist muscle groups is more impaired. Ayalon et al. (2000) argue that the study by Van den Berg-Emos et al. (1996) completed several tests on one day which could have lead to fatigue, although only two repetitions were performed on the same day. In the study conducted by Ayalon et al. (2000), a greater number of repetitions were performed on two different days.

Fowler et al. (2001) found that maximal effort exercises with the quadriceps femoris muscle did not increase spasticity. According to Daminao, Martellotta, Quinlivan, and Abel (2000), a decrease in concentric torque is found when velocity increases. The higher the speed, the greater the spasticity or restraint from the antagonist muscle, which in effect will result in a decrease in measured strength of the agonist muscle. In eccentric testing, the restraint of the spasticity of the antagonist muscle will not occur because the antagonist muscle is shortening while the agonist is lengthening. Any effects on eccentric strength can therefore not be due to spasticity. Any spasticity due to the stretch reflex will be to the agonist muscle and may enhance torque production in the agonist. They found eccentric and concentric muscle weakness in persons with spastic cerebral palsy compared to those without cerebral palsy (mean age = 10.3 ± 2.6 yr). The knee eccentric / concentric

ratios were significantly higher ($p < 0.05$) in persons with cerebral palsy than those without, with no significant difference in the ankle ratios.

Strength training for persons with cerebral palsy should follow the same progressive overload principles that are used for persons without cerebral palsy. Because cerebral palsy is the results of impaired neurological control, the muscle itself is unaffected. The muscle should therefore be able to derive the same benefits from resistance training than the muscles of a non-cerebral palsy athlete (Dompier, 2001). Strength training does not by itself increase spasticity or decrease flexibility. Stretching before and during strength training sessions is recommended to ensure that the spasticity does not increase and reduce flexibility (Steadward, 1998). Dompier (2001) highlighted that strength training programmes should not only be specific to the person's needs, but also specific to the disability. For example, rhythmical, repeated strength exercises can reduce spasticity, but rapid and near maximal efforts can result in more spasticity (Holland, McCubbin, Nelson & Steadward, 1994a).

Excessive fatigue should be avoided because fatigue leads to even more deterioration in the control of movement patterns. This can be accomplished by modifications in the intensity, duration, volume and frequency of training of the athlete (Dompier, 2001). An extended warm-up period with large rhythmical movements is recommended, with stretching before and after resistance training (Dompier, 2001). People with athetoid cerebral palsy should be encouraged to focus on relaxation. Coordination and complex movement patterns would be more difficult for the ataxic cerebral palsy person and strength training exercises should take this into account (Dompier, 2001). The use of medication taken to address conditions such as spasticity and epilepsy related to cerebral palsy, needs to be taken into consideration when planning training programmes.

Aerobic Endurance

Prolonged exercises using large muscle groups will train your aerobic endurance capacity (ACSM, 1995), which is “the ability of the body to utilize oxygen efficiently are seen as improved endurance” (ACSM, 1995, p. 156). A direct relationship has been found between the frequency, duration and intensity of training and improved cardio-respiratory fitness (ACSM, 1995).

The body's ability to utilize oxygen is measured by assessing the change in VO_2 max in both able and disabled athletes (Holland et al., 1994). VO_2 , which is a person's oxygen consumption, is measured directly by multiplying the cardiac output by the arteriovenous oxygen difference (Withers, Gores, Gass & Hahn, 2000). Holland et al. (1994) defined VO_2 max as "the maximal rate at which oxygen can be consumed by the body per minute, and represents the greatest difference between the rate at which oxygen enters and leaves the lungs" (p. 687). It is typically evaluated by measuring pulmonary ventilation and then comparing the inspired and expired carbon dioxide and oxygen concentrations (Withers et al., 2000).

Cardio-respiratory endurance is influenced by the ability of the body to take-in and use oxygen and by the ability of the body to rid itself of carbon dioxide (AAPERD, 1980). Winnick and Short (1985) defined cardio-respiratory endurance as "...the ability of an individual to perform large muscle or whole body activities continuously for a sustained period of time" (p. 37).

Aerobic Endurance and Cycling

Coyle (1995) provided the following definition: "Endurance performance ability is the sum and interaction of many factors and every person is unique in his or her pattern of physiological attributes (p.25). Improved endurance allows the cyclist to feel more comfortable on the bike for longer periods without exhaustion (Burke, 2002). Friel (2003) defined endurance as "...the ability to continue working despite the onset of fatigue" (p. 47).

Hawley and Stepto (2001) designed a model for endurance cyclists based on Coyle (1995). For cycling the maximum sustainable power output is the indication of performance ability. The training stimulus, (composed of the volume, intensity and frequency of training, recovery and years of endurance training) results in skeletal muscle adaptations (Hawley & Stepto, 2001). Skeletal muscle adaptation in its turn will result in maximal sustainable power output necessary for performance in cycling (see Figure 2).

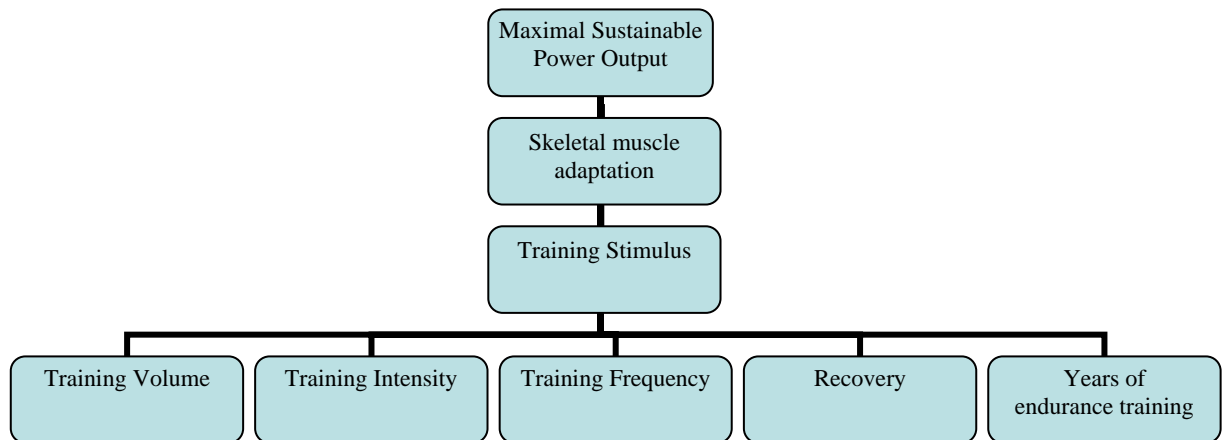


Figure 2

Factors important for the training stimulus that influence the maximal sustained power output (adapted from Hawley & Stepto, 2001).

Skeletal muscle adaptation is a product of various physiological adaptations in response to the training stimulus. Physiological factors influenced by the training stimulus are the skeletal muscle morphology, the rate at which the major fuel sources are utilized during prolonged, intense exercise and the capacity to buffer muscle and blood hydrogen ions concentrations (Hawley & Stepto, 2001). A critical adaptation that takes place due to endurance training is the ability of highly-trained cyclists to oxidize less carbohydrates and more fat during prolonged, intense exercise at the same absolute work rate (Hawley & Stepto, 2001).

Coyle (1995) associated good endurance performance to the interaction of what he called “performance abilities” and “functional abilities:”

Performance Abilities.

1. Performance Oxygen Consumption (VO_2)

Performance VO_2 is the highest rate of aerobic energy expenditure, possible for the cyclist to maintain over the given duration of the event. Together with the measurement of respiratory exchange ratio it provides the measure of energy expenditure (Coyle, 1995).

2. Performance Power (PO)

Performance power is the rate of power production that the cyclist is capable of generating for the specific period of time, expressed in watts (Coyle, 1995). Power can be expressed as absolute or relative values.

Functional Abilities.

1. Economy of movement.

The measurement of power generated relative to the energy expenditure measured from VO_2 , the watts produced per liter per minute of oxygen consumed (Coyle, 1995).

2. Lactate threshold VO_2 .

This is the intensity a cyclist may be able to maintain during a 3 hr cycle or the VO_2 at which a 1 mM increase in lactate within the blood is first seen (Coyle, 1995).

3. Lactate threshold power.

This is the power output that corresponds to the lactate threshold (Coyle, 1995).

4. Gross mechanical efficiency.

The percentage of chemical energy converted to mechanical work, with the remainder lost as heat. It is largely related to muscle fiber type composition (Coyle, 1995).

5. Maximal oxygen consumption (VO_2max)

It is the highest rate of oxygen consumption possible during large muscle mass activity. VO_2max is largely a function of stroke volume, aerobic enzyme activity and muscle capillary density (Coyle, 1995).

• **Track Cycling.**

Aerobic energy contributes to 85 % of a male cyclist's energy production in the 4000 m pursuit and 75 % of the female 3000 m pursuit, with 50 % energy contribution during the 1000 m time trial for males and 35 % during the 500 m time trial for females (Craig & Norton, 2001). A high aerobic power with peak values in excess of 80 ml/kg/min for male track cyclist, and 70 ml/kg/min for female track cyclists is associated with track cycling success (Craig & Norton, 2001). Research has shown that peripheral and central components of aerobic metabolism contribute to track cycling performance (Craig & Norton, 2001). Good correlations have been found between the power output at which blood lactate thresholds occur and performance of track cyclists (Craig & Norton, 2001). However when peak power output is compared with maximal aerobic capacity as predictors of performance, PPO is a better predictor than VO_2max (Coyle, 1988).

• **Road Cycling.**

Martin et al. (2001) reported that female road cyclists in the USA and Australia had VO_2max values between 57-64 ml/kg/min, with higher values up to 71 ml/kg/min previously tested. They also reported that the aerobic power output achieved by the US national team road cyclists averaged at 333 ± 21 W or 5.5 W/kg. Lucia et al. (2001) discriminated between testing protocols and indicated that with long incremental protocols of four minutes per interval, the values recorded for male road cyclist were 400-450 W or 6.0 -6.5 W/kg. Short incremental protocols show a higher power output of 450-500 W or (6.5-7.5

W/kg). Mean values of 5 -5.5 Watts/kg and VO₂max of 70-80 ml/kg/min are good values, with the light uphill climb specialist having the best values (Lucia et al., 2001).

Coyle et al. (1991) found that elite cyclists had 11 % higher power output during a 1 hr time trial than non elite cyclists. This was closely related to the percent of Type I muscle fibers, which had a high correlation with the number of years of training. The elite cyclists' higher power output was highly correlated with the power produced on the "downstroke" of the cycling action. Although they stated that VO₂max is not a predictor of performance, they did note that % VO₂max at lactate threshold together with capillary density, accounted for 92% of variance in a time to fatigued test.

Aerobic Endurance and Cerebral Palsy

Low cardiovascular endurance is common in persons with cerebral palsy (Poretta, 2000). The ACSM (1997) determined that individuals with cerebral palsy present with higher heart rates, blood pressure, and lactate concentrations when performing at submaximal work rates than their able-bodied peers, as well as a 50 % lower maximal physical work capacity. A person with cerebral palsy therefore needs more energy to perform a given task (Jones & McLaughlin, 1993; Winnick & Short, 1985). The "waste" of energy can be due to the exaggerated movements, especially in athetoid movements, or the development of spasms that resist movements (Shephard, 1990). Gait abnormalities are responsible for the "waste" of energy, and the increase in submaximal walking energy expenditure for persons with cerebral palsy is as much as three fold (Maltais, Pierrynowski, Galea & Bar-Or, 2005; Unnithan, Dowling, Frost & Bar-Or, 1999).

Co-contraction (antagonist and agonist muscle contract simultaneously) was found to be a major factor in the increased energy cost during walking for children with cerebral palsy (Unnithan et al., 1996). Unnithan et al. (1996) observed that the oxygen cost at 3 km/h was significantly higher for children with cerebral palsy than for their able-bodied peers, but when the oxygen consumption was correlated with 90% of each person's fastest walking speed, no difference was found between the two groups. Implications are that children with cerebral palsy work at a higher level of their aerobic power, and would therefore fatigue more easily in prolonged exercise (Unnithan et al., 1996). Although the authors found that co-contraction plays a major role in the energy expenditure, they

contended that it is not the only reason for the higher energy cost and that further research is needed for more clarification. In persons with cerebral palsy the co-contraction index in the lower leg muscle groups explained 42.8% ($r=0.663$) of the variance in the VO_2 , with the thigh co-contraction index explaining 51.4 % of the variance ($r=0.717$)(Unnithan et al., 1996).

The purpose of a study by Bowen, Miller and Mackenzie (1999) was to determine if oxygen cost was directly related to the level of function in gait patterns (i.e. comparing subjects with different levels of constraints to walking). They compared the oxygen consumption of individuals with muscular dystrophy and individuals with cerebral palsy, where the functional level of the individuals was the same. The results revealed a statistically significant difference in oxygen cost and oxygen consumption between the individuals with cerebral palsy and muscular dystrophy. The individuals with cerebral palsy had higher oxygen cost in performing the same task.

Treatment of individuals with cerebral palsy is aimed at making an individual more functional (Bowen et al., 1999). Mechanical efficiency was defined by Jones & McLaughlin (1993) as “the energy required to complete a given amount of work, divided by the actual amount of energy released in performing the work” (p.614). Efficiency can be used to determine if treatment has improved the functioning of an individual. Dwyer and Mahon (1994) acknowledged that there is a lack of knowledge regarding athletes with cerebral palsy and their response to graded exercises testing. The assessment of submaximal and maximal exercise capacity is an important tool as part of the physiological assessment for athletes. Ventilatory threshold and peak oxygen uptake are measurements of the maximal and submaximal exercise capacity tests. Dwyer and Mahon (1994) defined ventilatory threshold (VT) as “a disproportionate increase in pulmonary ventilation with respect to the increase in oxygen uptake. The nonlinear increase in ventilation has been linked to an excessive increase in anaerobic energy production” (p. 329). The importance of the VT is for determining training intensities. Training under the VT indicates that long duration of training would be possible. Holland et al. (1994) suggested that VO_{2max} is more reliable and a better indication of cardiorespiratory fitness than ventilatory threshold for persons with cerebral palsy.

It had been thought that low oxygen uptake could be the reason for fatigue in children with cerebral palsy, but a study by Rose, Haskell and Gamble (1993) discovered

that the oxygen uptake for children with cerebral palsy is the same at a given submaximal workload than for non-cerebral palsy children. It is suggested that additional factors and local factors as well as subjective feelings of fatigue may rather be the reason to terminate exercises than reaching maximal oxygen uptake early.

Training Aerobic Power and Aerobic Endurance

Endurance training is the first physiological aspect that needs to be nurtured before any other training is introduced in the training plan of cyclists (Friel, 2003). Improvement in a road cyclist's performance is largely dependent on the adaptations through training that enable a rider to increase energy production and delay the onset of muscular fatigue (Burke, 2002; Hawley & Stepto, 2001). To increase the aerobic energy production, the morphological components need to be adapted to enable a change in the performance indicators (Coyle, 1995; Hawley & Stepto, 2001). VO_2max of novice cyclists will improve during the course of a training year, but once a cyclist reaches a well-trained level, VO_2max will not increase with training intensity and volume (Lucia et al., 2001). However, other research about the effect of high intensity interval training on the improvement of VO_2max indicated that it does improve VO_2max , but still more improvement was seen in less experienced cyclists (Jeukendrup & Martin, 2001). It appears that the % VO_2max at lactate threshold is closely related to performance and training should focus on improving this aspect (Lucia et al., 2001; Coyle, 1995).

Burke (2002) summarized the importance of endurance training as follows:

1. Increases in the body's potential to store carbohydrates within the muscle and liver;
2. Improvement in the cardio-respiratory system, allowing more oxygen to be delivered to the working muscles; the expiratory phase is longer during high workloads and the tidal volume shows no plateau at near maximal intensities.
3. Increased pumping efficiency of the heart to enable it to pump more blood per minute to the working muscles; ventricular hypertrophy due to training (Lucia et al., 2001).
4. Improved thermoregulation by increasing blood flow to the skin while cycling;
5. Better neuromuscular efficiency of pedaling technique;

6. Increased ability to burn more fat during long road races;
7. Improved endurance of the cycling muscles by increasing the number of mitochondria.

Improved endurance ability prepares the body for the harder sessions to come. The better this preparation, the better the adaptation to the rest of the year's training (Burke, 2002). Little research is available on the physiological adaptations in elite cyclists, but the effects of training in moderately fit individuals are well documented.

Lucia et al. (2001) noted the following regarding metabolic and neuromuscular changes during a season for a professional cyclist:

1. Lower circulating lactate levels at submaximal intensity.
2. Enhancement of motor unit recruitment in active muscles.
3. No significant changes in the blood pH and HCO₃ levels at given workloads, this means that there is no significant improvement in the buffering capacity of the cyclist. In contrast, amateur cyclists show improved muscle buffering capacity. However, laboratory high intensity training in other studies has resulted in improvement in muscle buffering capacity of competitive non-professionals.

High intensity training was shown to produce improved lactate transport and result in an increased lactate threshold in sedentary cyclists, and most of the changes occurs after 8 -12 weeks of training at ventilatory and lactate thresholds (Londeree, 1997). It has been recommended that a part of the base training for elite cyclists should be replaced by sustained 5-minute aerobic interval sessions (Hawley & Stepto, 2001). Burke (2002) recommended that the longest endurance ride should not exceed more than 25 % longer than the cyclist's longest racing distance. This was supported by Friel (2003), who related endurance to different training methods in this way:

Definition	Training method
Endurance is the ability to continue work despite the onset of fatigue.	<ul style="list-style-type: none"> • Start in off season with cross training. • Duration of endurance rides should be at least as long as the longest race.

The following is a summary of Gregor and Conconi's (2000) description of how to train aerobic power and endurance:

Physiological variable	Goal of Training	Intensity	Frequency / Duration
Aerobic power	Stimulate the development of both oxygen transport to the tissues and aerobic fuel breakdown.	Just below anaerobic threshold	Generally it can be repeated every 3 days. Start off with 5 min intervals, can progress to 20 min. Rest equals interval time, or is shorter 2:1 (work:rest).
Aerobic endurance	To enhance the use of fatty acids and sparing of glycogen.	15-20 % below the anaerobic threshold.	Prolonged sessions starting with 30 min to several hours.

Aerobic training can also take the form of active recovery. Active recovery rides are at lower than 65 % of HR_{max} and of short duration. They do not result in any physiological changes, but help the body to recover after intense training sessions, or prepare the body for intense training sessions to come (Burke, 2002).

Anaerobic Endurance and Anaerobic Power

Power represents the coordinated application of strength. Power was defined by Miller (1995) as the speed or rate of a muscular contraction. It requires that force be generated quickly, with strength and speed the two main qualities (Brandon, 2003; Fleschler, 2002). Muscle power is also defined as the mechanical work performed per unit time (Parker et al. 1992; Tirosh, Bar-Or & Rosenbaum, 1990). Power is measured in Watts (W) and for maximal power output of short duration the major source of energy is from the ATP-CP system (Fleschler, 2002).

$$\text{Power (W)} = \text{Force (N)} * (\text{Distance (m)} / \text{Time (s)}) = \text{Work (J)} / \text{Time(s)} \text{ (Knuttgen, 1995)}$$

To develop power, intra-muscular and inter-muscular coordination is necessary for neuromuscular adaptations to take place (Fleschler, 2002). Intra-muscular force during a muscle contraction is depended on the number of motor units involved in the movement, the change in frequency at which the motor nerves fire or a combination of the two. While

inter-muscular coordination requires complex coordination and efficiency of numerous muscle groups depending on the movement's antagonist and agonist muscle groups (Fleschler, 2002).

Power in sport can be determined for one single movement or a series of movements (Knuttggen, 1995). Peak muscle power can be determined with the Wingate Anaerobic Test (WAnT). This 30-second test is a good indicator of anaerobic endurance capacity and the 10-second test is good for determining peak muscle power (Zajac, Jarzabek & Waskiewicz, 1999).

Anaerobic capacity is based on the determination of the maximal accumulated O₂ deficit (Medbo, Mohn, Tabata, Bahr, Vaage & Sejersted, 1988). For the purpose of this study, anaerobic capacity for the cyclists was defined as the average power output achieved during the 30-second WAnT test.

Anaerobic endurance capacity is primarily dependent on the effectiveness of the glycolytic metabolism. Research by Zajac et al. (1999) demonstrated that during the 30-second anaerobic test the glycolytic system is responsible for 56% of the energy and the ATP-PC system 28%. During the first 10 seconds, phosphagen breakdown is responsible for most of the energy.

Coyle (1995) observed that there is a lack of clarity regarding the exact cause of the onset of blood lactate accumulation during anaerobic training, as well as a lack of clarity in the terminology used to describe "anaerobic threshold". The increase in blood lactate during cycling is partly a result of the disturbances in muscle cell homeostasis, but is also influenced by muscular capillary density and the amount of muscle mass used for the cycling action (Hawley & Stepto, 2001; Coyle, 1995). Therefore, instead of "anaerobic threshold", the term "lactate threshold" is more frequently used, but still not always consistently. Some authors defined the onset of blood lactate accumulation (OBLA) as the intensity where the blood lactate is increased by 1mM, while others defined it as the intensity where the blood lactate rises above 4mM (Coyle, 1995).

Anaerobic Endurance, Anaerobic Power and Cycling

The contribution of the anaerobic energy system is often indicated by high post-exercise blood lactate levels (Craig & Norton, 2001). However, professional road cyclists

need to possess a high anaerobic threshold, at nearly 90% of VO_2max (Lucia et al., 2001), indicating a delay in utilizing the anaerobic glycolytic system. Burke (2002) noted that one of the problems for endurance cyclists is their inability to fully use their muscular strength in explosive type situations like sprinting a short hill or acceleration at the beginning of a sprint. Power training can be done in gymnasiums with weights or using plyometrics, but should always be made functional on the bike by doing power training on the bike as well (Burke, 2002).

- **Track Cycling.**

Anaerobic endurance and peak muscle power is very important for track cyclists (Friel, 2003). Road cyclists need power and anaerobic capacity to bridge gaps after a break away, to break away or to finish strongly at the end of a race (Van Diemen & Bastiaans, 2002).

De Koning, Bobbert & Foster (1999) concluded that the cyclist with the highest anaerobic peak power output and an all out pacing strategy will achieve the best results in the 1000 m track time trial. Peak power output during the start of the 1000 m of one male cyclist at the World Cup was 1799 W, with 78% decrease in power output towards the end. The average power output was 757 W (Craig & Norton, 2001).

Power outputs during the 4000 m individual pursuit and the 3000 m individual pursuit at the World Cup events were paced evenly, with an average power output for the males in the 4000 m pursuit of 495 W, and 381 W for the females in the 3000 m individual pursuit (Craig & Norton, 2001).

- **Road Cycling.**

Muscular endurance, power and 'speed-endurance' are three physical components that play a role in the anaerobic capacity of a cyclist (Friel, 2003). The ability of a cyclist to repeatedly cycle at a high cadence against high resistance is seen as muscular endurance. This enhances the cyclist's ability to sustain greater speed for a longer period of time, which is known as 'speed-endurance'. 'Speed-endurance' is the ability to resist fatigue at high speed. It is

important during long sprints and is a blending of power, strength, muscular endurance and cardio-respiratory endurance (Friel, 2003).

Anaerobic Endurance, Anaerobic Power and Cerebral Palsy

Individuals with cerebral palsy have difficulty in producing force at a high tempo (Damiano et al., 2000). The co-contraction of the muscles increases as speed increases (Parker et al., 1992). Powerful movements demand coordination of the muscles and rapid contraction, which is not always possible for persons with cerebral palsy (Winnick, 1990; Winnick & Short, 1985).

The WAnT assesses peak muscle power as well as mean muscle power. The test has been found to be highly reliable and reproducible when testing individuals with cerebral palsy (Parker et al. 1992; Tirosh et al., 1990). Tirosh et al. (1990) reported a correlation coefficient between Test 1 and Test 2 of $r=0.90$ ($p<0.001$) in spastic CP subjects for peak power and $r=0.95$ for mean power achieved during a WAnT. Parker et al. (1992) found that children with various severity and anatomical distribution of cerebral palsy had subnormal values of peak and mean anaerobic muscle power of the upper limbs as well as the lower limbs. Children with cerebral palsy were found to score 2-6 standard deviations below the mean for age-matched healthy populations in peak power and total mechanical work when tested with the Wingate anaerobic test (Bar-Or, 1996).

Training Anaerobic Power and Endurance

The following is a summary of Gregor and Conconi's (2000) explanation of how to train anaerobic power and endurance:

Physiological variable	Goal of Training	Intensity	Frequency / Duration
Anaerobic power	Improving anaerobic alactic(non-glycolytic) power	Maximal	Short duration 7-8 seconds, repeated 10 times, with 2 min rest. Maximal 3 sets. Can be performed every day, should start about 1 month before season starts.
	Improving anaerobic lactic (glycolytic) power	Maximal	Medium duration of 30 seconds, repeated 3 -5 times, with 5 min recovery. With 2- 3 sets. 20 min of easy recovery between sets. Maximal 3 times a week, starting 1 month

			before competition.
Anaerobic Endurance	To develop the ability to do prolonged work at high lactate production.	High intensity	60 sec and longer intervals, repeated 3-5 times, with little rest about 3 minutes.

Friel (2003) described different training methods to develop what he called different “racing abilities” as follows:

Racing Abilities	Definition	Training the racing ability
Speed	The ability to move quickly. In cycling it is the ability to cycle at high cadences.	Through out off season and pre season, high cadence with light resistance should be incorporated in training.
Power	The ability to apply maximum force in shortest possible time. Very important for track sprinters.	Short intervals at maximum pace, with long rest intervals.
Muscular Endurance	The ability of the muscles to sustain high loads for a prolonged time. In cycling it is the ability to turn a relatively high gear, at a high cadence repeatedly.	Start in mid winter with interval training at intensity of 89-93% of lactate threshold and gradually progress to intervals of 94-102 % of lactate threshold. Work intervals increase and rest decrease. The higher the intensity the shorter the interval (6-12 min) but muscular endurance can also be built doing longer rides (20-60 min) at slightly lower intensities.
Speed Endurance	The ability to resist fatigue at high speed. Necessary for races where long sprints are important.	Speed endurance work consists of intervals at lactate tolerance pace, and is quite stressful. Intervals between 3 -6 minutes.

Speed training was described by Burke (2002) as short intense periods of 5- 30 seconds with relative long recovery times of 2 – 5 minutes. It is the basis of quickness and explosive power. Sprint training is very specific and needs to be trained as a specific component. Burke (2002) suggested that sprint training should be incorporated at least once a week after a good base and should represent 3 - 5 % of the cyclist’s training time.

In summary, even though the three groups of authors use different terminology the training methods overlap, with Friel (2003) and Burke (2002) being more specific in their use of training terminology, than Gregor and Conconi (2000) were.

Motor Control and Coordination

“Motor control is the ability to regulate or direct the mechanisms essential for movement” (Shumway-Cook & Woollacott, 2001, p.1). Movement occurs because of the interaction between the individual, the task and the environment. That interaction results in a specific movement, called a specific action. Movement is a coordinated execution of all the muscles and joints involved in a specific action. The difficulty with coordination is that the capacity of one muscle to generate force does not predict the ability of that specific muscle to work as a unit in cooperation with other muscles to produce a coordinated action and generate a desired amount of force. “Thus the essence of coordination is the sequencing, timing, and grading of the activation of multiple muscle groups” (Shumway-Cook & Woollacott, 2001, p.141).

Motor Control, Coordination and Cycling

The pedaling action is a multiple joint action where timing and sequence of muscle activation result in the power produced during the cycling action. Each muscle needs to contract at specific timing resulting in maximum force on the pedals. Maximum muscle contraction should be during concentric contraction and minimum contraction during eccentric contraction resulting in the greatest power output during a cycling action (De Koning & Van Soest, 2002). The timing of each muscle contraction according to the cycling pattern is very important to result in the most efficient and powerful cycling action (De Koning & Van Soest, 2002; Broker & Gregor, 1996). One-legged pedaling can be a good way to train a good cycling pattern with limited force applied during the recovery phase of the cycling pattern and therefore improving muscle coordination and pedaling action (Broker & Gregor, 1996). It has been found that experienced cyclists have more efficient cycling actions (Broker & Gregor, 1996).

Motor Control, Coordination and Cerebral Palsy

A study by Jones and McLaughlin (1993) demonstrated that mechanical efficiency for individuals with cerebral palsy is lower than their able-bodied peers. Individuals with cerebral palsy have difficulties in planning movement patterns as well as executing them. Varying degrees of coordination problems are common (Poretta, 2000). Balance and body coordination due to abnormal movements and posture are also common, especially in

ataxia and athetoid cerebral palsy (Poretta, 2000). Poor reciprocal control of the extremities of the person with cerebral palsy is another characteristic (Kaplan, 1995).

Co-contraction is found to be a major factor in increased energy use at specific submaximal workloads. Co-contraction is defined as simultaneous activity of the agonist and antagonist muscles while a given task is performed (Unnithan et al., 1996). Excessive co-contraction and inadequate force production are frequently present in individuals with cerebral palsy (Unnithan et al., 1996). It is significantly higher in individuals with cerebral palsy than in non- cerebral palsied individuals. Although co-contraction increased as speed increased during walking with cerebral palsy, the increase is greater for cerebral palsied individuals (Unnithan et al., 1996). The increase in co-contraction will result in a less efficient cycling action for persons with cerebral palsy. During fitness testing at the USA disabled cycling training camp in 1993, it has been found that single leg below-knee amputation cyclists had a more efficient pedaling action, due to less negative force production during the recovery phase (Burke, 1996).

Training Motor Control and Coordination

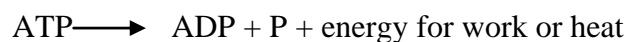
Isolated leg training, ergometer speed work and high speed spinning are recommended by Burke (2002) to improve pedaling action:

Isolated leg training	Start off at a slow cadence of 40 -60 rpm, to get the cycling action and coordination better. Focus on specific parts of the pedaling action etc. either the pushing down or pulling up part before combining it. As the cycling action improves, you can increase the cadence (Burke, 2002).
Ergometer speed work	Repetitions of increased cadences are used up to a cadence of 120 rpm (Burke, 2002).
High speed spinning	Cadences up to 140 rpm is maintained for 30 seconds with a 5 minute recovery in between (Burke, 2002).

Energy Systems and Cycling

Any training session required work because work needs to be done to ensure adaptation takes place and performance improves. The work consists of different volume and intensities that are needed or required to achieve the desired adaptations. Whenever work needs to be done, energy is required. Energy is therefore the cyclist's ability to perform work. Different volumes and intensities require the body to produce energy from

the different energy systems. Movement for the human body (work) represents mechanical energy that is supported by chemical energy derived from food fuels. Work for a cyclist is done by contracting the muscle fibers to overcome resistance. The energy needed to produce work is converted from food to the intra-muscular fuel which is converted into adenosine triphosphate (ATP) (Jeukendrup, 2000; Bompa, 1999). When ATP is broken down, energy is released.



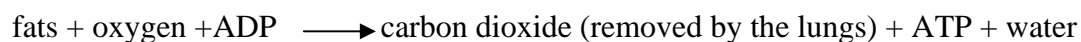
A limited amount of ATP is present in a muscle cell before any work is done. Thus ATP will only last for about two seconds and it is therefore important to have energy systems in your body to produce more ATP. ATP links the energy-yielding and the energy requiring functions within all cells (Plowman & Smith, 1997). The three systems responsible for producing ATP in the body are (Jeukendrup, 2000; Bompa, 1999; Burke 1995):

1. The oxidative system.
2. The phosphagen system.
3. The glycolytic (lactate) system.

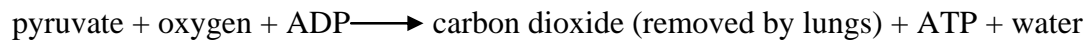
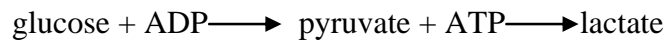
Energy can be broken down aerobically (in the presence of oxygen) or anaerobically (the absence of oxygen).

The Oxidative System

The oxidative system is also known as the aerobic system and it produces energy from carbohydrates (glucose and glycogen) or fats. In events longer than 20 minutes, fat becomes an important source of energy. The system is a slower producer of ATP, although it produces a greater amount. As performance time increases, the proportion of ATP production from the oxidative system becomes greater (Jeukendrup, 2000; Bompa, 1999; Burke, 1995). The breakdown of fats (intramuscular triglycerides as well as free fatty acids mobilized from adipose tissue) is as follows:

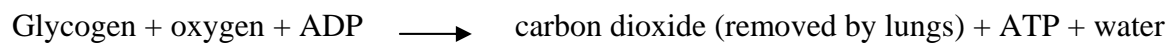


The breakdown of carbohydrates (glycolysis) is more complex and takes place in two successive reactions.



Lactate can also be oxidised, but there is controversy whether this is first requiring conversion back to pyruvate or not (Gladden, 2004).

When the exercise is light, the lactic acid is directly oxidised in the second phase and the result is:



The two energy systems relying on oxygen work together and overlap. Depending on the intensity of exercise, the proportion of each type of oxidative energy that is used differs. Fats are used mainly for low intensity exercise, and as the exercise intensity increased the proportion of carbohydrates become a more important source of energy (Jeukendrup, 2000). The oxidative systems provide energy during low intensity exercise.

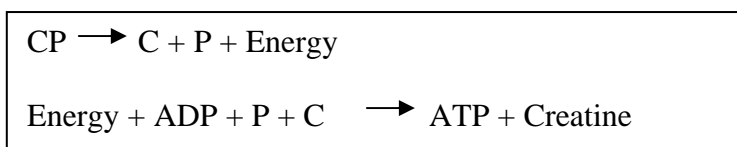
Training the Oxidative System. Janssen (2001) described different intensities of training that use the oxidative energy system, starting with types of training where limited lactate is accumulated.

Training Type	Definition	Training Intensity
Recovery Training	Recovery training. No physiological adaptations, other than recovery and rest.	70% of HR max. Duration :30-90minutes
Extensive endurance	Extensive distance training. To improve fat oxidation.	70-80% of anaerobic threshold or 70-80% of HR max. Distance: 100-200km
Intermediate endurance	Medium distance training. Oxidation of fats and carbohydrates.	80-90% of anaerobic threshold or 80-85% of HR Max. Surpass race distance once a week.
Long intensive endurance	Interval workouts. Intensive distance training	90-100% of anaerobic threshold or 85-90% of HR max. Interval training duration between 8-15 minutes repeated 4-5 times. Recovery time 5 minutes. Stop training if fatigued.
Short intensive Endurance	Interval workouts. Long resistance training.	100-110% of anaerobic threshold or 90 % of HR max.

	Oxygen system activated completely	Interval training duration between 2-8 minutes repeated 5 – 8 times. Recovery time 4-6 minutes.
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The Phosphagen System

The phosphagen system can produce energy for about 10 seconds before it is depleted. The system consists of the combined stored ATP and creatine phosphate. It does not need oxygen nor has a by product of lactate. In every muscle cell there is a limited amount of creatine phosphate or phosphocreatine (CP). When energy is needed rapidly, the CP breaks down into creatine (C) and phosphate (P). The energy released by the breakdown of CP is used to resynthesised ADP + P into ATP. This energy released by the breakdown of CP can't be used directly by the muscle for contraction, since only ATP can be used directly (Janssen, 2001; Jeukendrup, 2000).



The phosphagen system is responsible for energy during the first burst of activity and is very important for activities that are explosive, short, rapid and powerful.

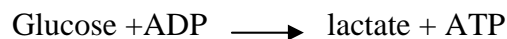
Training the Phosphagen System. Janssen (2001) described training of the phosphagen system in the following way:

Energy System	Definition	Training the energy system
Phosphagen system	Sprint training. Anaerobic and alactic.	Maximum energy supply up to 10 seconds, with good rest of up to 5 minutes.

The Anaerobic Glycolytic (lactate) System

The anaerobic glycolytic system provides energy when the demands on the oxygen system are too high or when the phosphagen system has been exhausted. It can provide energy for a maximal effort up to 3 minutes. This energy is produced through an anaerobic breakdown of muscle glycogen (stored carbohydrates) and blood glucose. At this point lactate is produced in the muscle due to the inability of the oxidative system during the second phase of glycolysis to oxidise the pyruvate formed in the first phase. The lactate

keeps accumulating in the muscle and a condition known as acidosis occurs (Jeukendrup, 2000; Burke, 1995)



Muscle ‘burning’ is a characteristic symptom of high utilization of the anaerobic glycolytic system due to the increasing acidosis in the muscle. Different energy systems are therefore important for the different training intensities and volumes, as well as for different physiological adaptations that are needed for performance. Since intramuscular measurements were not done, it is beyond the scope of this literacy review to discuss the adaptations. The energy systems are therefore the physiological basis of training for performance.

Training the Anaerobic Glycolytic System. Janssen (2001) described training the anaerobic glycolytic system in this way:

Energy system	Definition	Training the energy system
Anaerobic glycolytic	Short resistance training. Anaerobic and high intensity training based on anaerobic glycolytic energy provision.	Maximum energy supply 2 -3 minutes, with limited rest (depending on level of fitness) Only once a week, with a recovery ride to follow the session.

Tactical and Technical Factors Important For Cycling Performance

“Performance abilities are the product of certain discrete functional abilities,” Coyle, 1995, p. 26). In an article by Jeukendrup and Martin (2001), the authors argued that training is the most important factor in improving cycling performance. Large improvements can be made by relatively small changes in body position, modifications of equipment and altitude training.

A variety of internal and external factors play a role in cycling performance. Internal factors can be divided into training and nutrition, with external factors being the biomechanics of the body and aspects of the bicycle and the aerodynamics of the combination of the body and bike.

Pacing

Atkinson & Brunskin (2000) defined pacing strategy as “the with-in race distribution of work-rate (power-output)” (p. 1449). Pacing is of importance in races where the competitors need to beat the clock in order to beat the competitors, so the ability to cycle as fast as possible without knowing what your opponent is doing is very important (Foster, Snyder, Thompson, Green, Foley & Schrager, 1993). Limited research was found regarding pacing strategy in the track and road time trial events although scientists feel that pacing can play a major role in the outcome of competition (Atkinson & Brunskill, 2000; De Koning et al., 1999; Foster et al., 1993). All-out pacing during the 1000m time trial proved to obtain the maximal performance outcomes, with a pacing strategy of an all-out start for the 4000 m pursuit followed by constant power output after the initial 12 seconds (De Koning et al., 1999; Foster et al., 1993). This can be compared to a high intensity fixed workload time to exhaustion test in the laboratory using an electronically braked cycle ergometer.

During the 1998 world championships, a good correlation was found between the first and last lap time, with a decrease of nearly 78% in power output of one of the cyclist's competing (Craig & Norton, 2001). Atkinson & Brunskill (2000) found that cyclists tend to start too fast in a race where equal head and tailwinds are predicted, and that they will benefit up to 10 s on a 16.1 km time trial if a constant pace is selected. An even better recommendation is that cyclists should cycle at a constant pacing strategy when the environmental conditions are constant, but should adopt a variable power-strategy where hilly or wind conditions will play a role. Power output rather than heart rate is best to measure pacing strategy during a race (Atkins & Brunskin, 2000).

Cadence

The optimal cadence for a cyclist is usually selected by the cyclist according to the rate at which he feels most comfortable. To produce a constant external power output, a cyclist can choose to either cycle at low cadence with high pedal resistance or at a high cadence with low pedal resistance, or something in between (Widrick, Freedson & Hamill, 1992). Ryschon and Stray-Gundersen (1991) stated that if a cyclist does not know what his/her optimal cadence is, a relatively high cadence is normally selected. Different cadences have different effects on the metabolic variables, biomechanical aspects such as

muscle stress functions, muscular moments and muscle recruitment patterns as well as cardiorespiratory variables.

Research has shown that cycling at 60 rpm results in a lower heart rate and VO_2 than at 80 rpm at the same workload (Ryschon & Stray-Gundersen, 1991; Coast & Welsch, 1985, Hagberg, Mullin, Giese & Spitznagel, 1981). An increase in pedaling rate has a significant effect on physiological parameters such as the respiratory exchange ratio and lactate production, even with no increase in resistance (Hagberg et al., 1981). Marsh and Martin (1998) found that there were no differences in RPE rating at cadences between 65 - 95 rpm in a trained cyclist. The fact that the most economical cadence rate is at 60 rpm but the RPE indicated that the preferred cadence was higher, could indicate that cyclists who are used to cycling at a certain cadence will simply perceive that cadence to be better. The feedback from muscle activity can also influence the perceived effort at lower cadences (Neptune & Hull, 1998, Ryschon & Stray-Gundersen, 1991). An optimal pedaling cadence by a trained cyclist can be one at which neuromuscular fatigue and muscle force is minimized. This seems to appear at cadences close to 90 rpm for trained cyclists (Neptune & Hull, 1998; Hagbert et al., 1981). The neuromuscular fatigue cadence for recreational riders is found to be at approximately 70 rpm (Takaishi, Yasuda, Ono & Moritani, 1996). Elite cyclists who cycle at 90rpm at 80% of their VO_{2max} , are considered to be the most economical (Hagberg et al., 1981).

Cyclists with different muscle fiber types would prefer the use of different cadences (Hintzy, Gros Lambert, Dugue, Rouillon, & Belli, 2001). At submaximal velocity the slow twitch muscle fibers will be recruited for the lower cadences (60 rpm) with the fast twitch fibers recruited for the faster cadence (100rpm) (Hintzy et al., 2001). At high intensity exercise of 85-90% of VO_{2max} in prolonged exercise fast twitch muscle fibers are recruited together with the slow twitch muscle fibers. This increased recruitment of fast twitch muscle fibers results in a non-linear effect on oxygen consumption with the increase of cadence (Londeree, Moffitt-Gersenberger, Padfield & Lottman, 1997). When the cadence decreases at this intensity the amount of force at e.g. 50 rpm increase and more fast twitch fibers are necessary to produce the power. If the cadence is kept at 90 rpm, less muscle force is necessary per pedal stroke and this might result in a greater use of the slow twitch muscle fiber. This in turn can describe the higher mechanical efficiency at higher cadences (Takaishi et al., 1996).

Widrick et al. (1992) found that trained cyclists will choose a cadence that will optimize their biomechanical variables rather than their metabolic variables. Swain & Wilcox, (1992) found that a cyclist cycling uphill in a seated position at a cadence of 84 rpm was the most economical, but this was not always perceived as the best cadence by cyclists.

An increase in cadence can have an influence on the coordination of the pedaling action, especially at the transition phases (switch between flexion and extension of the leg) of the cycling action. Neptune, Kautz, & Hull (1997) found a higher degree of muscle activation of the gastrocnemius and hamstring muscles at the bottom of the cycling action as cadence increased.

During the 1998 world championships a cyclist competing in the 1000 m time trial had an average cadence of 127 rpm (Craig & Norton, 2001). If a higher force or power output is required, it is better to have a higher cadence to reduce the force per stroke that needs to be overcome. De Koning and Van Soest (2002) mention two important factors influencing optimal cadence for track cycling. First of all, at a high cadence less force can be produced during the period of contraction and a low cadence might seem the best, but on the other side concentric muscle power production depends on muscle shortening velocity. This results in a point where an optimum of both is met and this will be the greatest cadence for sprinting. De Koning and Van Soest (2002) considered 120- 130 rpm to be the best cadence selection for sprinting.

When considering cadence selection, this literacy indicates that at fast velocities of force application individuals with cerebral palsy might find it difficult due to coordination. Does a cadence at 120-130 rpm during track cycling influence the result badly due to the coordination problem? In the current thesis cadence will be assessed.

Sitting or Standing Position on the Bike

Cycling in a standing position is mostly used to increase power output during sprinting, hill climbing or just for brief periods during flat terrain cycling to release saddle pressure (Ryschon & Stray-Gundersen, 1991). A study by Ryschon and Stray-Gundersen (1991) indicated that standing cycling results in a 12% higher VO_2 and a 8% higher heart rate. This indicates that cycling in a standing position results in an increase in cardio-respiratory and metabolic requirements. A brief explanation can be that cycling in a

standing position is either less efficient or the work rate of riding in this position is higher. A higher degree of muscle activity throughout the whole body is visible, and the body needs to generate not only power to cycle but also to support the body in the standing position. The fact that cyclists perceived cycling standing as easier, can be attributed to the fact that the workload is spread over more muscle groups and the fatigue in one muscle group is not perceived as that severe, even though the energy contribution is more (Ryschon & Stray-Gundersen, 1991).

Uphill cycling sitting at a cadence of 41rpm or standing at a cadence of 41 rpm, resulted in no significant difference in physiological variables, but cycling uphill sitting at a cadence of 84 rpm has a higher economy than either of the other two (Swain & Wilcox, 1992).

Body and Bike

The air resistance is the dominant resistance force on a flat terrain and various factors determine the air resistance from which the frontal surface area of the bicycle and rider is one. During outside cycling in calm conditions at speeds of 8.9 m/s air resistance is responsible for 90% of the total resistance during motion (Ryschon & Stray-Gundersen, 1991).

Bicycle Mass

Improvements of between 29 seconds to 7 minutes have been found when a 7 kg bicycle was used rather than a 10 kg bicycle when doing hill work on gradients of 3.6 & 12%. These improvements were higher for non-elite than elite cyclists (Jeukendrup & Martin, 2001).

Aerodynamics

Aerodynamics is a product of the bike, the body position on the bike and the wheels the cyclist is using. Two components of air resistance that a cyclist can control are the frontal surface area and the speed of the bicycle (Ryschon & Stray-Gundersen, 1991). A cyclist cycling at 40 km/h uses 90% of the power generated to overcome air drag (Coyle, 1995). Different body positions, bicycle frames and the correct wheels can improve performance times with great effect (Jeukendrup & Martin, 2001). For example, by

changing the handle grip from the top of the handlebars to the “drops” on the handlebars, the air resistance is reduced, aerodynamics improved and the drag of the rider and the bicycle is reduced (Ryschon & Stray-Gundersen, 1991). The difference in the two grips has no impact on energy expenditure (Ryschon & Stray-Gundersen, 1991).

Planning the Training Year

The systematic approach to planning the training year that was adopted in this study was periodisation. Periodisation can be traced back to the Ancient Olympic Games (Hoffman, 2002; Bompa, 1999). According to Hoffman (2002), the basis of periodisation is “the manipulation of training volume and intensity, in conjunction with appropriately timed short unloading phases, the athlete can reach peak condition at the appropriate time, and minimize the risk for overtraining” (p.8). Bompa (1999) explained that the word periodisation originates from the word “period”, which is portion or division of time. The general characteristics of the periodisation approach to planning are:

1. A breakdown of the yearly training plan into phases, and then into smaller units, that can be sequenced to build toward peak performance (Bompa, 1999).
2. A structure for training within each phase and unit that is aimed at the development of all of the athletes’ abilities to the highest level (Bompa, 1999).

Planning

Planning is the art of using science to structure a training program. In training nothing happens by accident, but by design. You don’t plan work, but the physiological reaction to the training. (Bompa, 1999, p.150)

The challenge when planning training sessions is to determine what should be done on one day, that will contribute to maximal performance on the day of a competition (Hawley & Stepto, 2001). In order to meet this challenge, every training session should be planned to enhance some adaptation whether it is anatomical, physiological, biochemical or psychological (Impellizzeri, Rampinini, Coutts, Sassi & Marcora, 2004). In the periodisation approach, the primary means for training for adaptations is through manipulation of various training stresses called the “variables of training” (Friel, 2003; Bompa, 1999). These training variables are:

- Volume: The total quantity of activity performed in training (Bompa, 1999).
- Duration: The length of the training session (Friel, 2003; Baechle & Earle, 2000).
- Intensity: The quality component of the work during training (Friel, 2003; Baechle & Earle, 2000; Bompa, 1999).
- Frequency: The number of training sessions per week or per day (Friel, 2003; Baechle & Earle, 2000; Bompa, 1999).
- Density: The relationship between work and recovery phases of training (Bompa, 1999).
- The Exercise Mode: The specific activity performed on the given day (Baechle & Earle, 2000).

The periodisation approach suggests that adaptations will be achieved when the training variables are manipulated according to the “principles of training” (Friel 2003; Bompa, 1999). These principles include:

- Individualisation: This principle refers the performance manager recognizing that each individual will adapt to training stimuli differently, and that difference must be taken into consideration when planning (Friel, 2003; Bompa, 1999).
- Specificity: This principle refers to the performance manager targeting “distinct adaptations to the physiological systems that arise from the training programme” (Baechle & Earle, 2000, p. 493), and ensuring that “the stresses applied in training must be similar to the stresses expected in racing” Friel (2003, p. 15). Bompa (1999) proposed that coaches should assess the type of training that works for improving a specific type of performance in a specific athlete and that future training sessions should follow this model. Bompa (1999) called this modeling and proposed that modeling during practice sessions was a technique that promoted specificity in training. Therefore, modeling is a method to design training that takes into account the specifics of the sport in an attempt to make adaptation more precise.

- Progression: This principle refers to the performance manager gradually increasing the challenges in training by varying the training variables (Friel, 2003).
- Overload: Because adaptation only takes place if the physiological system is exercised beyond the level that it is accustomed to (Baechle & Earle, 2000), the performance manager must ensure that the training sessions involve overload. Bompa (1999) combined the principles of progression and overload into the concept of “load progression.”

The manipulation of the variables of training according to these principles occurs within each training session, each session must fit into the training phase and each phase into the sequence of phases designed to meet the goals of the training year (Bompa, 1999). Although adaptations will only occur if stimulation is high enough, an athlete cannot keep training day after day at a high level, so time must be provided for recovery and regeneration (Steinacker, Lormes, Lehmann & Altenburg, 1998). A structured training programme will incorporate daily, weekly and monthly training at high loads and recovery loads to ensure that both the training response and the recovery response are induced (Steinacker et al., 1998). Soungatoulin, Beam, Kersey & Peterson (2003) found that a periodized high intensity cycling programme had better effects on fitness and time trial performance of able-bodied cyclists than did the “traditional” programme of constant, high intensity exercise. The exact training methods were not described.

The Training Phases

Each training year is organised into training phases called macro-, meso- and microcycles (Steinacker et al., 1998). Each of the cycles consists of sequenced daily training programmes that focus on a specific adaptation that is important for performance in selected competitions. Different terminology is used in the training literature to describe how to periodize training. Friel (2003) identified Bompa as the world-recognised expert in periodisation, and for that reason, Bompa’s (1999) terminology and interpretations will be used in this study:

1. Phases in the training year: Preparatory, competitive and transition.
2. Sub-phases within each phase: General preparation, specific preparation, pre-competitive, competitive and transition.

3. **Macrocycles:** The breakdown of sub-phases into smaller segments (length varies).
4. **Microcycles:** The breakdown of the macrocycles into smaller cycles (length varies).

Hoffman (2002) used the term mesocycle to describe the different phases in strength or power training and the term microcycles to describe the transition cycles between two mesocycles. Arnheim & Prentice (2000) and Baechle & Earle (2000) used the term macrocycle to describe a training period that can last from one year to several years, the term mesocycles as the different training phases in a macrocycle, lasting several weeks to several months and the term microcycles the training periods in a mesocycle, lasting anything from one to seven days.

Phases of the Training Year

Preparatory phase. Bompa (1999) described the preparatory phase as the time where a general foundation of physical, technical, tactical and psychological preparation is developed for the competitive phase. During the preparatory phase, the volume of training and the intensity is moderate. The duration of this phase depends on the annual plan. A beginner cyclist's preparation phase will be longer than that of an experienced cyclist because it will take more time for the beginner to develop a general foundation, where the experienced cyclist can build on the foundation from previous years of training

The duration of a preparation phase is normally between three to six months. In individual sports, the duration of the preparatory phase should be twice as long as the competitive phase (Bompa, 1999). Burke (2002) supported this approach, including the division of the preparation phase into two shorter phases: the general preparation phase and the specific preparation phase.

- General preparation phase.

The objective of the general preparation phase is to develop a high level of physical conditioning that can support future increases in intensity in the training. Bompa (1999) suggested that any short-cuts in the general preparation phase can lead to poor performance, lack of consistency and even a decrease in performance as the season progresses. He stated that one-third of the preparation phase should be spent on general preparation

(Bompa, 1999). For more elite cyclists, the duration of this phase may decrease.

Training variables in the general preparation phase:

1. Volume and duration: Training volume and duration should be adapted according to the cyclist's cycling age and competition distance. Jeukendrup and Martin (2001) have advised that high training volume and duration are essential for performance. Daily training duration of 2 – 4 hours was recommended by Burke (2002) or not more than 25 % plus the racing distance. Volume should never increase with more than 25 % per week.
2. Intensity: The training should never exceed anaerobic threshold and should therefore be between 60-80% of the cyclist's maximal heart rate. High intensity exercise should not exceed more than 30-40% of the training volume and should only be maintained for a short duration (Gregor & Conconi, 2000; Bompa, 1999). Hawley and Stepto (2001) also emphasized the importance of high intensity training for cycling performance and proposed that interval duration of 5 min was optimal.
3. Frequency: A high frequency of training for 5-6 days per week was recommended by Burke (2002).
4. Exercise mode: Training in this phase should be general and should focus on the specific skills of the sport. The development of aerobic endurance and strength with weight training are the main objectives of this phase. 70-80 % of training time should be spent on enhancing aerobic endurance during this phase (Bompa, 1999). Resistance training should focus on building a foundation and on basic strength (Burke, 2002). Training to enhance aerobic endurance can be done by doing different aerobic activities and cycling should not be the only training method to enhance aerobic capacity. Mountain biking for a road cyclist is an excellent way of preparing a cyclist during the preparation phase (Burke, 2002). A cycling cadence of 90 rpm was recommended by Burke (2002).

- Specific preparation phase.

This phase represents a transition leading to the competitive phase. The remaining time left in the preparation phase after general preparation, is spent in specific preparation (Bompa, 1999).

Improving and perfecting technique and tactical elements become the focus in this phase (Bompa, 1999). Racing opportunities are included in the training programme (Burke, 2002). The emphasis should still be on the development of endurance, speed and power. The volume and intensity of training reaches its maximum during the middle part of this phase (Burke, 2002).

Training variables in the specific preparation phase:

1. Volume and duration: Although volume of training is high at the beginning of this phase, 70-80% of the training will be focused specifically on the skills and technical aspects of sport performance. Towards the end of this phase, volume of training should decrease (Bompa, 1999).
2. Intensity: Physiologically, cycling requires an increase in intensity during this phase. Interval training, power-sprints, hill training and anaerobic-threshold training are typical ways of preparing the body for the competitive phase. The intensity on some training days reaches 85-95% of maximal capacity. It is important to incorporate recovery days in between hard training days (Burke, 2002).
3. Frequency: A high frequency of 5-6 days per week was recommended by Burke (2002). It is important to incorporate recovery days in between hard training days (Burke, 2002).
4. Exercise mode: Training includes general endurance and resistance training, but it is focused on developing the energy systems needed for the cycling. Resistance training for cyclists enters the power phase. To fulfill the goals of perfecting technique and skills required for cycling, specific exercises that stimulate the prime movers for cycling actions

should be included in the programme (Bompa, 1999; Burke, 1995).

Races entered during the specific preparation phase are seen as “training races” and not for the purpose of achieving personal bests or winning the race.

Friel (2003) described the preparation phases as base phase lasting up to a total of three months. Endurance training takes 75% of the training time during the first month, with strength and speed training for the remaining time. During the second month, muscular endurance is added to strength and speed training and approximately 50% of the training time is focused on these three variables. The third month shows an increased emphasis on muscular endurance training and a slight decrease in strength training, with endurance training still requiring 50% of the training time. Martin, Scifres, Zimmerman & Wilkinson (1994) suggested that one type of aerobic interval training could consist of 30 minutes intervals at 80% of maximal HR and that this intensity of work would require a 1:1 work:relief ratio.

Competition phase. The objectives of the competition phase are to improve sport-specific abilities, to consolidate technique, to improve performance and to gain competition experience, while physical preparation is maintained (Burke 2002; Bompa, 1999). The competition phase is where all the different areas (physiological, psychological, tactical) should come to a peak. The challenge in this phase is to continue to maintain the strength and endurance gained during the preparation phase, but also to achieve optimal results during competition.

During the competition phase long and heavy training loads cannot be sustained week after week. Usually a taper of 2 weeks is recommended prior to a competition (Martin et al. 1994). This can be achieved by scheduling planned recovery periods within the competitive phase, but these should not compromise the need to peak for a critical competition (Burke, 2002). Sport-specific skills and exercises along with actual competitions occupy the major portion of this phase. It is important that the cyclist spend about 90% of his/her training time in activities that will contribute directly to performance in competition (Bompa, 1999). The competition phase can be broken down into two phases, the pre-competitive phase and the main competitive phase.

- Pre-competition phase.

The objective of the pre-competition phase is to test the cyclist's ability in a series of less important competitions and to make changes towards the cyclist's training programme, tactics, psychological and mental preparation in response to feedback from his/her performance (Bompa, 1999).

Training Variables in the Pre-Competition Phase:

1. Volume and duration: Training is very specific to the demands of competition, but the training programme is not tapered prior to competition in this phase. The volume is higher than in the main competition phase, but much lower than in the specific preparatory phase (Bompa, 1999). The duration of this phase depends on the number of competitions that have been entered to shape the cyclist for the main competition.
2. Intensity: The intensity of training increases during this phase and is specific to race requirements (Friel, 2003).
3. Frequency: The density of training (the ratio between high intensity and recovery sessions) starts to increase. More recovery time is needed.
4. Exercise mode: The mode(s) chosen will be specific to competition.

Friel (2003) described the pre-competition phase as the "build-up phase" where endurance training is cut a little bit, with increased focus on high intensity training such as muscular endurance, speed endurance, strength and with the addition of power training.

- Main competition phase.

The objective of the main competition phase is to achieve top performance in the main competition by successfully drawing on all physiological, tactical, nutritional and psychological resources needed.

Training Variables in the Main Competition Phase:

1. Volume and duration: Volume should be reduced (Bompa 1999), with one endurance ride per week, at approximately the competition distance.

2. **Intensity:** Two to three sessions a week should be of high intensity, with the highest level of intensity reached two to three weeks before main competition. After the highest intensity is reached, the intensity should drop progressively (Bompa 1999).
3. **Frequency:** The frequency of training is not as important as the density of training at this stage. Density of training is the ratio between high intensity and recovery sessions. The purpose of the competition phase is not to build fitness, but to sharpen skills for the main competition. Good recovery sessions is therefore of great importance (Bompa, 1999).
4. **Exercise mode:** This need to be specific to your races. Race training is very important during this phase (Friel, 2003).
5. **Tapering or super compensation:** The objective of tapering or super compensation is to give the body a chance to recover from training fatigue, and to achieve optimal psychological preparation in order to achieve optimal performance (Bompa, 1999). The importance of getting the balance right between maintaining optimal fitness and minimum fatigue is the aim of tapering (Burke, 2002). Each cyclist's tapering time may differ. Too short a period for tapering may leave a cyclist tired, and a too long a period for tapering time may lead to reduction in the training effect.

When the cyclist is used to training twice a day, two training sessions a day at lower intensity is recommenced during the first week of unloading. During the second week of unloading, no high intensity training or weight training is recommended. For every 1 ½ days of work there is ½ day of rest.

Transition Phase

The transition phase serves as the time period between the end of your competition phase and the beginning of your general preparation phase for the next training year. It serves as a time where you can recover physically and mentally from the competition phase (Burke, 1995).

Training variables in the transition phase:

1. Volume and duration: The duration of the transition phase should never be more than 8 weeks. Volume should be moderate to low (Burke, 1995).
2. Intensity: Intensity of training during this phase should be moderate to low. Emphasis should be on enjoyment and maintenance of a reasonable fitness (Friel, 2003; Bompa, 1999).
3. Frequency: It should be an active recovery period with as little structure as possible (Friel, 2003).
4. Exercise mode: Different exercise modes should be used to change the training environment (Friel, 2003; Bompa, 1999).

Monitoring the Training Programme

The system of periodisation of training works better if training is monitored. Table 10 presents a summary of the methods typically used to monitor training that were reviewed by Hopkins (1991). A brief indication of the positive and negative aspects of each method is also provided. It can be noted on Table 10 that monitoring is not only gathering feedback on daily training, but also monitoring the effects of the phases of the programme. The effects of the programme are most effectively monitored by the administration of physiological evaluations (Bompa, 1999). Hopkins (1991) is in agreement and adds that part of the quantification of training is the physiological monitoring regarding the effect of training.

Table 10: Summary of the methods to monitor training by Hopkins, 1991, pp. 164-168)

Methods	Positive Aspects	Negative Aspects
<i>Physiological monitoring</i>		
1. Oxygen consumption	<ul style="list-style-type: none"> • Very stable measurement of training intensity. • Valid and reliable. 	<ul style="list-style-type: none"> • Expensive. • Specialized equipment necessary. • Difficult to administer.
Heart rate	<ul style="list-style-type: none"> • Easy to administer. • Objective. • Valid and fairly reliable. • Motivational. 	<ul style="list-style-type: none"> • External factors can have an influence on heart rate and the true intensity is not always recorded. • Expensive.

		<ul style="list-style-type: none"> • Heart rate monitor failure.
Blood lactate	<ul style="list-style-type: none"> • Objective. • Valid and fairly reliable. 	<ul style="list-style-type: none"> • Impractical to monitor each training session. • Expensive. • Nutrition and previous training can influence results.
Direct observations	<ul style="list-style-type: none"> • All aspects of training can be monitored. • Objective and subjective. • Very accurate objective measurements by means of time, speed, etc. 	<ul style="list-style-type: none"> • Finding qualified observers who can be scheduled for observations. • Time consuming.
<i>Self-reports</i>		
Retrospective questionnaires	<ul style="list-style-type: none"> • Easy and cheap to administer. • Can gather information about any aspect of training over any period of time • No interference with training programme. 	<ul style="list-style-type: none"> • Subjective. • Misunderstanding of questions. • Details of experiences can be forgotten. • Distorted responses.
Diaries	<ul style="list-style-type: none"> • More valid data than retrospective questionnaires due to the immediate completion after training sessions. 	<ul style="list-style-type: none"> • Compliance often low. • The huge volume of data. • The interpretation of data time consuming. • Reliability and validity of diaries questionable.

More recently Seiler and Kjerland (2006) have combined some of these above-mentioned monitoring techniques, such as using both heart rate monitoring and ratings of perceived exertion and relating these to physiologically determined effort zones. More sophisticated methods are likely to be tested in future, but little scientific evidence is published to promote complicated methods of training monitoring.

Monitoring Physiological Variables

Information gathered from physiological tests gives no direct feedback regarding the mode, frequency, duration or skill components of the training, but rather the effect of the training (Hopkins, 1991). Tests to monitor the effect of training on cycling performance are an integral component of the training programme with cycle ergometers as basis for most of the tests (Paton & Hopkins, 2001). Advanced technology makes it possible to monitor some physiological variables in the field (Craig & Norton, 2001). Tests that measure specific physiological variables (VO_2 max, lactate threshold) and tests

requiring self-selection of pace (constant duration and/or constant distance tests) are recommended (Paton & Hopkins, 2001).

The WAnT is used in many laboratories to determine anaerobic capacity and peak muscle power. Peak muscle power is the maximal power generated by the muscle and the anaerobic capacity is the total power that the muscle can produce using anaerobic sources (Palmer, 2002). Maximum accumulated oxygen deficit (MAOD) is also used to describe anaerobic capacity (Martin et al., 2001). This test is a supramaximal test lasting up to 1 minute in which oxygen consumption is measured. Thereafter the actual oxygen consumption required for the work done is predicted from the linear relationship between submaximal power output vs. oxygen consumption. The MAOD is the difference between the predicted oxygen required and the oxygen utilisation measured (Scott, Roby, Lohman & Bunt, 1991).

In this study, a variety of physiological measurements were used to monitor the effects of training experienced by the subjects. A brief description of each of these measurements is included in Chapter Three.

Monitoring of Training Sessions

Monitoring of training sessions is important for controlling the quantity and quality of training sessions, and in some cases to prevent overtraining (Avalos et al., 2003; Craig & Norton, 2001). Quantification of training can be motivational and can help with training prescription (Hopkins, 1991). Quantification of training can be assessed by retrospective questionnaires, diaries and direct observations of training behavior, as well as physiological monitoring (Hopkins, 1991). Physiological monitoring typically consists of fitness tests that provide feedback regarding physiological and sport specific performances related to the sport (Hopkins, 1991).

Two critical aspects of training to monitor are the volume (quantity) and intensity (quality) of training (Bompa, 1999). Technology available to monitor cycling training is power output or heart rate combined with the distance, time and average speed. The intensity of the cycling training session can be the average speed, the percentage time in a heart rate zone or average watts obtained, while the volume of a cycling training session can be either the time or the distance covered (Bompa, 1999).

Monitoring power output provides information that can help the performance manager advise the coach about how to refine the physical preparation of cyclists (Martin et al., 2001). A heart rate monitor is the most frequently used instrument to measure the level of intensity (Impellizzeri et al., 2004; Lucia et al., 2001). One areas for improvement of software for monitoring of training would be the capacity to determine a recovery value after intense training (Lucia et al., 2001). An area of technology that has recently improved is the use of power output monitoring devices on the cyclist's own bicycle, e.g. the SRM system that determines power from a device attached to the crank or the Powertap system using a device attached to the rear wheel hub. These devices were recently compared by Bertucci, Duc, Villerius, Pernin & Grappe (2005). The SRM system was found to be better at high intensities whereas the Powertap was as good as the SRM system at submaximal intensities. These systems are currently expensive and not widely used.

Rate of perceived exertion is also used to describe intensities of training sessions and has been found to be a valid way to gather information about intensity of training (Foster, Florhaug, Franklin, Gotshall, Hrovain, Praker, Doleshal & Dodge, 2001).

Research has been completed that has attempted to quantify what is called the training impulse (TRIMP) of training sessions or different cycles or phases (Esteve-Lanao, San, Earnest, Foster, & Lucia, 2005; Foster et al., 2001). Foster et al. (2001) developed a new way of using the TRIMP to incorporate different training zones. They found that using Rate of Perceived Exertion (RPE) or heart rate zones make no significant difference in measurement of the training load. Adaptations to the TRIMP concept have been used to define the training load in sports such as soccer (Impellizzeri et al., 2004), endurance running (Esteve-Lanao et al., 2005), swimming (Avalos et al., 2003; Mujika et al., 1996) and cycling (Foster, Hoyos, Earnest & Lucia, 2005; Lucia et al., 2003). Steinacker et al. (1998) recorded the number of minutes per day as an indicator of the training load of rowers.

Summary

Descriptive studies regarding training practices and elite athletes are limited. Most research articles regarding training practices have focused on intermediate to high level athletes, and not true elite level athletes. To quote Hawley and Stepto (2001), “...unfortunately, answers to these questions cannot be based on the results from well controlled studies undertaken on elite cyclists because such data does not exist” (p. 512). Hopkins, Hawley & Burke (1999) have noted that research on the effect of training programmes on actual competition is seldom undertaken. In the literature search for this study, limited information was found on the effect of periodisation of a full training year. Research regarding tapering and or the effect of different training protocols on physiological aspects are more common. For example, a study by Mujika et al. (1996) studied the effect of training on performance and assessed the response to tapering in elite swimmers.

Some literature regarding periodisation over multiple microcycles does exist. In one study, RPE was used to determine training load for seven weeks during a competitive season for soccer players (Impellizzeri, 2004). A study in 2003 by Avalos et al., described the relationship between training performances over three seasons for swimmers. The level of the swimmers was not mentioned in the study. A 24-week study on national and regional cross country runners in Madrid in terms of the effect of the training on their performance was conducted (Esteve-Lanao et al., 2005) The authors of this study highlighted the fact that limited research has been conducted on training load with elite level athletes based on heart rate data. A review article, Mäestu, Jürimä, & Jürimäe (2005) raised the point that studies monitoring training only over one microcycle limit the knowledge about sustainable training load.

When looking at descriptive studies regarding training practices of athletes with disabilities, the studies are even more limited. The study by Liow & Hopkins (1996) found that for athletes with disabilities competing at international level, the only aspect of their training that was optimal was the duration of the training phases, with a lack of specificity of training towards their specific event. Ineffective reduction in training intensity for an inappropriate duration of tapering was also found. In a thesis by Crawford (2004) a review of research in disability sport revealed that research topics include biomechanics, physiology, exercise physiology and sport psychology, but only three research articles on

training practices and persons with disabilities were found, covering wheelchair track racing and wheelchair road racing.

Rossouw's (2001) investigation into the training practices of elite athletes with disabilities discovered that in 1992, only 48 % of the athletes competing for South Africa at the Paralympic Games had followed a special training programme and only 26 % had participated in a weight training programme. In 2000 for the Sydney Paralympic Games, 69 % of the South African athletes had special training programmes, but again, only 26 % had participated in weight training programmes. In 1992, 65.7 % of the athletes perceived their preparation for the Paralympic Games as being good to very good, and in 2000 this increased to 83.3 %. This is an indication that training practices for elite athletes with disabilities are improving (Rossouw, 2001).

The emerging profession of sport performance management will hopefully build on the expanding body of knowledge in sport science and build a link to the coaches and athletes. The scope of performance management can include a variety of factors that affect performance, and consultations with experts from the different specializations in sports science, sports medicine and coaching will undoubtedly be part of the job. Attention to the individuality of each athlete is central to performance enhancement at the elite level, and this means that the sport performance manager will have to specialize in working with a limited number of athletes in a limited number of sports.

In the current study the enhancement of the performance of the elite cyclists was complicated by the possible effect of their cerebral palsy on their performance. Due to limited research in the field of elite cycling and cerebral palsy, this study will be the first research that describes and monitors the periodisation of training of elite cerebral palsy cyclists. The monitoring of daily training as well as the evaluation of physiological variables important for cycling was the main focus for data collections and interpretation, since the study was limited to the manipulation of selected direct factors.

Chapter Three

Methodology

The following chapter describes the design of the study and the procedures followed, as well as a description of how data was gathered and used to monitor training.

Design

The study is an example of descriptive research and as such, depends upon several measurement instruments to gather information about its focus of interest (Borg & Meredith, 1989). The research takes the design of a descriptive evaluative case study (Thomas & Nelson, 2001) and can be categorized as applied research (Barlow & Hersen, 1987). It is accepted in applied research that individual behaviour is a function of multiple factors and the interaction of events (Barlow & Hersen, 1987). This means that variability within each individual is expected and that there is no illusion that all the factors that affect behaviour can be controlled (Barlow & Hersen, 1987). Because the subjects in this study all had cerebral palsy, itself a source of variation, and because the topic was focused on elite level cycling, the research question was considered to be best answered using the case study design.

According to Thomas and Nelson (2001), a case study is a “form of descriptive research in which a single case is studied in-depth to reach a greater understanding about other similar cases” (p.280). Barlow and Hensen (1987) concurred, stating that the purpose of a case study is an in-depth understanding of an individual that may include efforts to affect changes in that individual.

The case study approach allowed the investigator to develop in-depth understanding of the training practices of each of the three elite cyclists (descriptive case study) as well as to try to effect improvements in the training of each cyclist by serving as their sport performance manager (evaluative case study). Because a case study can “provide insight and knowledge of a general nature for improved practices” (Thomas & Nelson, 2001, p. 282), it was considered to be appropriate for this time in the development of disability sport in South Africa. This kind of case study also encourages individual adaptations, feedback and interventions with each subject, which made it attractive to the subjects who were

eager to get additional support in their training for the 2004 Paralympic Games. Barlow & Hersen (1987) and Thomas & Nelson (2001) described some of the characteristics of descriptive evaluative case studies. These characteristics, with comments about how this study complied with each characteristic, are presented in Table 18.

Table 18. Compliance with the characteristics of a descriptive evaluative case study

Selection of Participants (Thomas & Nelson, 2001; Barlow & Hersen, 1987)	
Description	Random sampling is not used in most case studies. A project, individual, or institution is selected based on the problem being studied. The purpose is to study selected cases from which you can learn the most and extend the current knowledge base. Criteria for selection of subjects must be specific.
This study	Only elite cyclists with cerebral palsy were selected because performance management in the context of international level disability cycling was the phenomenon under investigation.
Gathering Data (Thomas & Nelson, 2001; Barlow & Hersen, 1987)	
Description	The methodology for gathering data during the use of case studies is very flexible and should be chosen according to purpose of the study.
This study	Methodology for gathering data during this study was by physiological monitoring and daily monitoring.
Analyzing Data (Thomas & Nelson, 2001; Barlow & Hersen, 1987)	
Description	The task of analyzing the data is made difficult by the amount of information gathered. Statistical analysis is not a prerequisite but a history of change is tracked, with comparisons between past and current status.
This study	The history of change on a variety of relevant variables is reported for each cyclist in the chapter devoted to his performance.
Repeated Measures (Barlow & Hersen, 1987)	
Description	A case study looks for variability within each person, and tracks that variation over a period of time.
This study	Certain physiological factors important for cycling performance were monitored over the course of the study, including time trials.
Choosing a baseline (Barlow & Hersen, 1987)	
Description	“The initial period of observation involves the repeated measurement of the natural frequency of occurrence of the target behaviors under study.” (p.71)
This study	Baseline testing was conducted during April 2003. The First Macrocycle provided insight into the individual status of each cyclist and how much it varied over time.
Phases and Length of Phases (Barlow and Hersen, 1987)	
Description	The study should be conducted in phases and each phase should be continued until some stability in the data is reached.
This study	Phase length was set at 21 weeks for each macrocycle. There were three macrocycles, each including a peak competition at the end of each phase. The fact that each macrocycle ended with a competition results in the ability to track changes in performance toward the final goal of achieving Paralympic success.

Procedures

The following sections describe the procedures that were followed in this research.

Permission to Conduct the Study

Since this study dealt with the training of cyclists for Paralympic competition, Disability Sport South Africa (DISSA) was first approached and asked if the investigator could approach potential Paralympic cyclists and invite them to participate in the project. A presentation of the format of the case study and the concept of periodisation of training was made to the General Manager, who immediately endorsed the project and informed all prospective subjects of DISSA's support for the research.

Selection of Subjects

Thomas & Nelson (2001) highlighted that the criteria for selection of a subject for a case study depends on the problem being studied. For this research, the criteria were that subjects must be elite level cyclists with cerebral palsy. "Elite" was defined as having previously represented South Africa in international cycling competitions. This put a strict limit on the number of eligible subjects. However, there was no scope for selection of "sub-elite" cyclists, since Hopkins et al. (1999) underlined the fact that elite athletes will have different training adaptations than recreational athletes to training interventions.

Five elite cyclists with cerebral palsy in the Western Cape, South Africa, were contacted to be part of this study. Four of the cyclists were male and one was female. All cyclists' had international experience and had top ten finishes in their different events at international competitions. The nature of the study and the time commitment was explained to each subject, and all five indicated that they wanted to participate. Each subject signed an informed consent form (see Appendix A) and initial testing was scheduled.

One male cyclist dropped out of the programme after the first round of testing due to retirement from competitive cycling. The female cyclist stopped cycling after the First Macrocycle when she found out that she would not be allowed to compete in the 2004 Paralympics. She was a tricyclist with relatively severe cerebral palsy. At the Paralympic level, it is required that there must be at least three qualified competitors for each event, or

that event will not be conducted. There simply were not enough female elite cyclists in her class to hold a Paralympic event. This reality was extraordinarily disappointing and led to a loss of motivation to train. In fact, she decided to stop competitive cycling.

Orientation of Subjects

First physical contact for testing was made with the cyclists after the cycling championships at the South African National Championships for the Physically Disabled in 2003.

Each cyclist received a questionnaire (see Appendix B) at the start of the programme to complete regarding his or her disability, factors that could have influence their training quality, as well as previous athletic involvement. The cyclists were then briefed on the concept of periodisation of training and three macrocycles were identified.

1. From the South African National Championships for the Physically Disabled, April, 2003 to the European Cycling Championships for Disabled, October, 2003.
2. From October, 2003 to the South African National Championships for Disabled, March, 2004.
3. From April, 2004 to the Athens Paralympic Games, October, 2004.

The cyclists were told that each macrocycle consisted of 21 weeks in total, and consisted of three mesocycles of 6 weeks, and a third tapering mesocycle of 3 weeks. The total number of weeks could vary slightly according to the needs of each cyclist. Each macro-cycle ended with a competition. The purpose of this discussion was to orient the cyclists to the phases during which their training would be monitored and during which advice would be given by the Performance Manager, but not necessarily indicating that the Performance Manager would provide specific training programmes.

The South African National Championships for Disabled in March, 2004, served as the national trials for the South African Paralympic Squad. In May, 2004, the Paralympic Team was announced. All three remaining cyclists in this research were selected for the Games.

Data Collection to Answer the Research Question

An evaluative case study not only involves a comparison between a beginning state and an ending state of a subject, but also traces what happens to the subject along the way (Barlow & Hersen, 1987). Jeukendrup and Martin (2001) identified that training was the single most important factor responsible for performance in elite cyclists, so performance assessment and monitoring of training were chosen as the sources for data to answer the research question that guided this study:

Can a sport performance management system that targets selected direct factors, be implemented successfully with cyclists with Cerebral Palsy in their preparation for competition at the elite level?

Selected direct factors:

- Performance assessment.
- Periodised planning of training.
- Feedback on training (training logs).
- Training sessions.
- Training camps.
- Sports medicine services and products.

Data to answer this question was gathered from two sources. First, information was gathered from the cyclists about their daily training, especially regarding volume, intensity, duration, frequency and specificity. Second, monitoring of the effects of their training programmes was accomplished by conducting physical assessments at the Stellenbosch University laboratories at the beginning, middle and end of each macrocycle.

Monitoring of Daily Training

Monitoring of daily training was done in two ways. Cyclists who had heart rate monitors used them as well as personal training logs to indicate the frequency, duration,

intensity and mode of their training each day. Cyclists who did not have a heart rate monitor used only personal daily training logs.

Heart Rate Monitoring. Although power output is a more direct way of measuring training intensity than heart rate monitoring, it is more expensive (Jeukendrup, 2002). A heart rate monitor may be a better indicator of physiological stress, but it does not always give an accurate picture of intensity of training (Jeukendrup, 2002). The heart rate monitor is seen to be a useful tool in monitoring exercise intensity. Polar® heart rate monitors were used to help with the quantification of training in this study. The manner in which each cyclist used the heart rate monitor is described in the report of each cyclist's training in the following chapters. When available, the data from each cyclist were analyzed using Polar Precision Performance Software®. Heart rate data was not always received on a monthly basis due to a problem regarding technology or the cyclists' breaks in training.

Daily Training Logs. Daily training logs are seen as valid means to quantify training (Hopkins, 1991). Daily training logs were provided to the cyclists to complete (see Appendix C for an example of a training log). The training logs included sections to complete volume, intensity, duration, frequency and mode of training as well as physiological variables important during the training period. Variables such as sleeping patterns, waking heart rate, weather conditions etc. were also included. These general training logs were given to the investigator on a monthly basis, as far as possible. The information on the training logs was used additional to the heart rate monitor data received from those cyclists' in possession of heart rate monitors.

Quantification of Daily Training. Quantification of training was done by using the information about the training variables gathered by either the heart rate monitor and/or the daily training logs. The TRIMP (Training Impulse) method has been developed to quantify the training load of an athlete (Esteve-Lanao et al., 2005; Foster et al., 2005; Impellizzeri et al., 2004; Avalos et al., 2003; Lucia et al., 2003; Foster et al., 2001; Mujika et al., 1996).

The concept of TRIMP: For each training session the training load is the product of the volume of training in a specific training zone multiplied by a fixed factor allocated to that intensity.

For this study the fixed factors were allocated as follow:

Recovery (<70% of HR max) = 1

Easy (70-80% of HR max) = 2

Moderate (80-85 % of HR max) = 3

Hard (85-100% of HR max) = 5

1. Volume of training.

Heart rate monitors: Total time spent during training as calculated by heart rate monitor.

Training logs: The time recorded by the cyclist on the training log was used to determine volume of training.

2. Intensity of training.

Heart rate monitors: A percentage of HRmax was used to determine the intensity of training and the time spent in each heart rate zone was calculated. Graphs consisting of training time in each heart rate zones were used to evaluate training intensity as part of the periodised plan. Percentage time per heart rate zone per week was calculated. Heart rate zones were defined as follows in the literature and the method used by Janssen (2001) was followed in this study:

Perceived Exertion (Burke ,1998)	% VO₂max (Burke, 1998)	% Anaerobic Threshold (Janssen, 2001)	% Max HR (Janssen, 2001)
Recovery	< 50%		<70%
Easy	50-75%	70-80%	70-80%
Moderate	75-84%	80-90%	80-85 %
Hard	>85 %	90-100%	85-90%
		100-110%	90-100%

Training logs: Perceived exertion adapted from Burke (1998) was used. Each cyclist needed to report whether each session was a training session or a recovery session, and whether the training was easy, moderate or hard. The number of sessions per week spent in each training zone was calculated from this information.

3. Frequency of training.

Frequency of training was determined by the number of training sessions a cyclist did during a week. Training sessions had to be at least three hours apart to count as a different training session otherwise it was recorded as one training session.

4. Training mode.

Each cyclist recorded the type of training activity each day. The different modes or activities differed between the different cyclists.

Physiological Monitoring

Repeated measures are seen as an important part of a case study approach to identify changes in “behavior” (Barlow & Hersen, 1987). These repeated measures are used to identify “problems” and make appropriate changes in treatment strategies to correct these problems (Barlow & Hersen, 1987). The schedule for repeated measures of physiological variables (physiological monitoring) is presented below. An attempt was made to test at the beginning, the middle and the end of each macrocycle, with the last testing of each macrocycle taking place as close as possible, preferably within a week after competition. In order to make direct comparisons between performance and competition results, fitness testing should take place within 1-3 weeks of competition (Martin et al., 2001).

First Macrocycle	Second Macrocycle	Third Macrocycle
April 2003	January 2004	Early June 2004
June 2003	March 2004	Late July 2004
October 2003		October 2004

Physiological monitoring was used to determine the effect of training on the physiological parameters important for cycling performance, as well as to evaluate areas that needed to improve for performance. Physiological fitness assessments were conducted according to the yearly plan (see the chapter for each case study for exact testing schedules). Each cyclist had a familiarization fitness assessment where all the tests were done. The first formal testing was done within a week after the familiarization session (baseline testing). Guidelines for diet and training before competition was given, but was not controlled.

The physiological assessments were adapted for each cyclist according to race distances. The testing was done on four separate visits (not consecutive days) to the laboratory with the breakdown of testing as follow:

Day 1: Anthropometry and Wingate Anaerobic Test.

Day 2: VO₂max with lactate.

Day 3: 1-Hour Distance Trial.

Day 4: 1 km & 3 km Time Trial / 7.5 km Time Trial

The details of these fitness assessments were as follows, with specific adaptations where needed for each subject noted in the case study:

Anthropometry. The same electronic scale was used to weigh the cyclists each time (Bw-150, UWE, Cape Town, South Africa). A skinfold caliper (Harpenden HSK-BI, British Indicators) was used for skinfold measurements. Humerus and femur breadths were measured with a small sliding caliper (Tommy 2, Rosscraft, Canada).

Anthropometry assessments were done according to the ISAK (2001) methods, by the investigator who is a certified grade 1 ISAK Antropometer. Two measurements were taken, with the average of the two used. Measurements taken were according to the measurements needed for the restricted profile used by the LIFESIZE® educational software for body composition analysis.

- The following skinfold measurements were taken: triceps, subscapular, biceps, iliac crest, supraspinale, abdominal, front thigh and medial calf.

- The following girth measurements were taken: arm relaxed, arm flexed, waist, gluteal, mid thigh, calf.
- The following breadth measurements were taken: humerus, femur.

The data were used to determine fat percentage and somatotyping, using the restricted profile of the LIFESIZE anthropometry software programme (Human Kinetics, Champaign, Illinois).

Wingate Anaerobic Test. The WAnT was conducted on a friction-loaded stationary cycle ergometer (Monark 834E) that was connected to a computer. A resistance of 7.5 % of body mass was used for the woman cyclist and 9.8 % of body mass was used for the male cyclists. This load was determined by the protocol used for testing athletes with disabilities in South Africa. The bicycle was set up to the preference of the cyclist. A warm-up of easy cycling for 10 minutes was allowed, after which 3 sprints of 5-10 seconds of fast pedaling were conducted. After a short rest, the test started when the cyclist was asked to cycle as fast as possible, and on the test administrator's judgment, the resistance weight was released as maximum revolutions per minute were achieved. The cyclist was not allowed to stand up during the test and verbal encouragement was given throughout the test.

The following variables were recorded as an average of 5 seconds:

1. Peak Sprint Power Output (Watts & W/kg)
Reliability ($r_s=0.94$; $p<0.001$)
2. Mean Sprint Power Output (Watts & W/kg).
Reliability ($r_s=0.95$; $p<0.001$)
3. Minimum Sprint Power Output (Watts & W/kg).
4. Fatigue Index (W/kg/s).

The WAnT has been found to be feasible (Tirosh et al., 1990) and reliable (Van der Berg et al., 1996) test to test anaerobic power and endurance for persons with spastic cerebral palsy. The study by Van den Berg used 10 diplegic children and 2 tetraplegic, while Tirosh et al. (1990) only specified that 27 of the children was spastic, 10 had athetosis, and 1 a combination of athetosis and ataxia.

Incremental Exercise Test to Exhaustion. The incremental exercise test is a well-known test to determine important physiological variables for endurance performance. Although VO_2max is not the most important predictor of performance it is a good indication of performance ability. Factors like lactate threshold at % VO_2max , VT_1 & VT_2 at % VO_2max , and maximal peak power output obtained during a maximal incremental test, are all found to be good predictors of performance (Baron, 2001; Lucia et al., 2000). Maximal heart rate is another physiological variable detected by the incremental exercise test to exhaustion.

Although various testing protocols are available for elite cyclists, no testing adaptation was made for cyclists with cerebral palsy for these testing protocols. The original testing protocol was therefore adapted for each cyclist. See each case study for specific protocol used. A combined technical error and biological variability for VO_2max has been reported by Katch et al. (cited in Withers et al., 2000) as 5.6 %, with Withers et al., reported a 2 % variability in well-calibrated equipment and well-habituated subjects (Withers et al., 2000).

The first incremental test was conducted on an electromagnetic stationary bicycle (BIKERACE – HC 600, Technogym, Italy). All the tests after that were conducted on a different electro-braked cycle ergometre (LODE BV Excalibur Sport) with pedal-force measurement (Groningen, The Netherlands). The cycle ergometer was set-up according to the preference of the cyclist, as close as possible to his/her own bike set-up. The cyclist had 10-15 minutes to warm-up as he/she preferred. The starting workload was set for CS1 and CS3 according to previous experience with these two cyclists prior to the study, so that at least 4 workloads could be completed prior to exhaustion. The starting workload for CS2 was the same as CS3, because they participate in the same classification. The increments were increased every 150 seconds and the test was completed when the cyclist could not cycle any more. The only criterion for ending the test was the inability to turn the cranks above 70 rpm. This was different from the convention for able-bodied cyclists, but based on experience of testing cyclists with cerebral palsy. A finger prick was used to sample blood for the lactate testing. A finger prick during the last 30 seconds of each workload was conducted as well as immediately post exercise. A handheld Accutrend analysis device (Roche, Germany) and lactate strips (BM, Roche, Germany) were used for the lactate concentration analysis. The Accutrend was calibrated whenever a new packet of lactate strips were opened. Before a blood sample was taken, the finger was cleaned with alcohol

and allowed to dry, before the finger was pricked. Care was taken that only the blood touched the lactate strip and not the finger. These precautions were taken to minimize the reported variability of measuring lactate concentration with the Accutrend (Swart & Jennings, 2004). La_2 and La_4 were determined by extrapolation from an XY-plot of lactate concentration vs. PO. The corresponding HR for the same PO was also determined from an XY-plot of HR vs. PO.

Continuous gas exchange data were collected using an automated breath by breath system (Triple V gas analyzer and JAEGER Oxycon Pro). Heart rate was continuously monitored during the test by using a heart rate monitor (Polar) as well as the heart rate connected to the Oxycon Pro. The heart rate data gathered by the Oxycon Pro, were used mostly, except if it was found to be faulty. Testing was kept to the same time of the day for all tests, except during the training camp in July, when this was not possible.

Data Capturing and Analysis:

- VO_2 , HR and RER were calculated for every workload by averaging the values of the last 30 seconds of each workload.
- Onset of blood lactate accumulation was taken as the workload or VO_2 where blood lactate concentration was 4 mmol/L.
- PPO was calculated as follows : Watts of final workload + [(time at final workload/150 sec) * increase in Watts per workload] (Hawley and Noakes, 1992).

The cycle ergometer (LODE BV) provides data regarding power output for each leg and the following data were available for each workload.

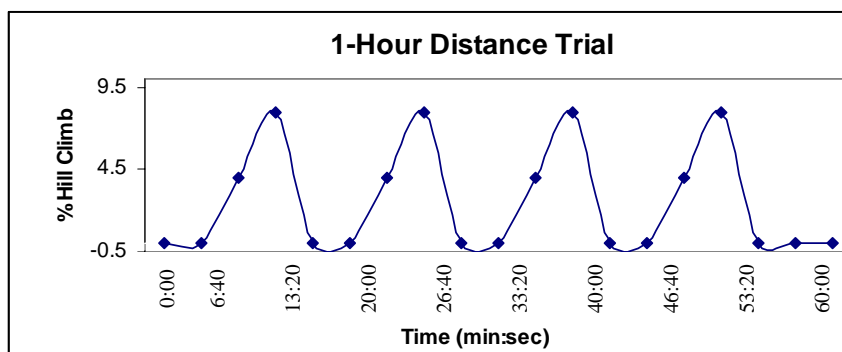
- Avg Watts per leg.
- Avg Max Watts per leg.
- Avg Min Watts per leg.
- Efficiency.
- Ratio per leg.
- Avg RPM.

The definitions for each of the following terms that were used in the interpretation of the data can be found in the Operator Manual Pedal Force Measurement for Excalibur (Sport) Version 2) and/or were confirmed by email communication (LODE BV; ask@lode.nl):

- Area of interest: Each workload was an area of interest as well as the total working time at the workload.
- Average Maximum Power: The average of all peaks of each revolution within the selected area of interest.
- Average Minimum power: the average of all minimums for each revolution within selected areas. Negative values indicate resistance against the pedals.
- Efficiency: The total torque (negative and positive) produced by both legs divided by the total positive torque by both legs. A value of 100 percent will indicate no resistant force on the pedals.
- Ratio: The part of total power that is generated by either the left or right side.

1-Hour Distance Trial. A one hour distance trial was conducted on a roller ergometer Spintrainer that has an electronic workload controlled system (Technogym, Italy). The cyclist provided his/her own bicycle to attach to the Spintrainer. The ergometer was calibrated for each cyclist before the test or warm-up was conducted and the tires were pumped to 8 bar. A speed and cadence sensor (Polar) was attached to the bicycle to collect data regarding speed and cadence selection during the test. Heart rate was also collected using a heart rate monitor (Polar S710) and data were collected every 5 seconds. The cyclist had a 10-15 minute warm-up as he/she preferred. The test was conducted as a race, with the cyclist allowed to take fluids at any time as well as to sit or stand whenever he/she felt necessary. Gear changing was allowed. An illustration of the hill climb and increments for the 1-hour distance trial is provided below (see Graph 1).

Graph 1. Visual illustration of resistance of 1-hour distance trial



A level 8 resistance was selected, as well as a protocol consisting of the following:

Time increments	Resistance
3:20	Flat
6:40	4 % Increment
10:00	8 % Increment
13:20	Flat
16:40	Flat
20:00	4 % Increment
23:20	8 % Increment
26:40	Flat
30:00	Flat
33:20	4 % Increment
36:40	8 % Increment
40:00	Flat
43:20	Flat
46:40	4 % Increment
50:00	8 % Increment
53:20	Flat
56:40	Flat
60:00	Flat

During this test, the cyclist was allowed to see the time, but not the speed or the distance covered. This was done to eliminate the motivation the cyclist would receive by seeing his/her distance or speed. Verbal encouragement was given throughout the test.

1 km & 3 km Time Trial. These time trials were conducted with the cyclists who competed in the track events to replace field testing and to simulate typical race distances

required for Paralympic competitions. A 1 km and 3 km distance trial was conducted on an electronic workload controlled system (Spintrainer; Technogym, Italy). Two hours rest between the two tests was allowed for recovery. The cyclist provided his/her own track bicycle to attached to the spintrainer. The bicycle was calibrated for each cyclist before the test or warm-up was conducted and the tires were pumped to 8 bars. A speed and cadence sensor (Polar) was attached to the bicycle to collect data every 5 seconds regarding speed and cadence selection during the test. The cyclist had a 10-15 minute warm-up as he preferred. The test was conducted as a race. A level 8 resistance was selected. The cyclist was allowed to see the distance cover but not the speed or time to limit extra motivation during follow-up testing. Heart rate was also collected using a heart rate monitor (Polar S710).

7.5 km Time Trial. This time trial was conducted with the cyclist competing in short road time trials and no track races. This distance was selected due to the nature of the time trial for these divisions at competitions. The time trial was conducted on an electronic workload controlled system (Spintrainer; Technogym, Italy). The cyclist provided his/her own bicycle to attach to the Spintrainer. The bicycle was calibrated for the cyclist before the test or warm-up was conducted and the tires where pumped to 8 bars. A speed and cadence sensor (Polar S710) was attached to the bicycle to collect data regarding speed and cadence selection during the test. The cyclist had a 10-15 minute warm-up as he preferred. The test was conducted as a race. A level 8 resistance was selected. The cyclist was allowed to see the distance covered but not the speed or time. Heart rate was also collected every 5 seconds using a Polar S710 heart rate monitor.

Data Reduction and Presentation of Time Trial Data: Due to the large amount of data collected, the time trial data were average into discrete bins as follow:

- 1 – hour Distance Trial: each bin represents 3 min 20 sec.
- 7.5 km Time Trial: each bin represents 0.5 km.
- 1 km & 3 km Time Trial: each bin represents 0.2 km.

However, on the graphs the data points for the different macrocycles and test occasions overlap and therefore the binned data points are presented with connecting lines, so that trends are more easily visible.

Interventions

Group Interventions. Three group interventions took place in the form of training camps. At the first day camp with the cyclists in 2003, a national Triathlon coach was asked to talk about periodisation, heart rate training zones, and training techniques.

At the second day camp in September 2003, a qualified physiotherapist specializing in cerebral palsy, had individual sessions with each of the cyclists. For some the question of bike set-up was discussed according to the postural adaptations due to the cerebral palsy. Exercises were given to each cyclist to improve certain weak areas as identified by the physiotherapist.

The third training camp was two weeks in length, and took place during the Third Macrocycle in July, 2004. During this training camp specialized coaching was conducted.

Individual Feedback. Depending on the different cyclists' needs, feedback regarding training and training programmes was given. Contact was made at least once a month with each cyclist. This will be discussed in more detail in each case study.

Feedback on the results of the physiological testing was given on the day as well as a report after the testing.

Other Interventions

DISSA allowed each team member of the South African Paralympic Team to apply for money to purchase better equipment, as well as other supplies and services that could assist each team members' preparation. The impact of these products and services for each cyclist will be discussed in each case study.

Each cyclist had a vision screening, medical screening, nutrition interview and psychological interview during the first Paralympic Training camp during May, 2004. If the different professionals identified a need in the above areas the cyclist were consulted by the professional and a plan of action was put into place. These interventions were not under the control of the investigator and will not be discussed in this study.

Report and Analysis of the Results

The results of monitoring training and performance testing are reported for each individual cyclist in case study format, with the training period of 18 months broken down

into three macrocycles. The investigator's perceptions of the impact of performance management on each cyclist are provided at the end of each macrocycle. Final conclusions about the effectiveness of performance management, both from the point of view of the investigator and each cyclist, are provided in the final chapter.

The Publication Manual of the American Psychological Association (American Psychological Association, 2001) was used in the technical preparation of this manuscript.

Summary

The case study approach was used in this study in order to gain in-depth insight into how sport performance management could be implemented to support the training of elite level cyclists with cerebral palsy. The first steps of the study were to select elite cyclists and determine the time frame of the research study. Different ways to monitor physiological variables during training, as well as means to evaluate the influence of the training programmes, were selected and applied according to protocols found in the cycling literature. Analysis of the data that were gathered during the monitoring process is presented in the following chapters to enable the reader to gain a clear picture of the impact of systematic training on each cyclist as an individual.

Chapter Four

Report of Case Study One

Personal Background

Case Study One (CS1) is a 22 year old male, tricycle cyclist competing in Division 2. His primary classification is C6, and his type of cerebral palsy is ataxia. Personal information was gathered during interviews with the cyclist as well as his parents. Although his limb control is good, his lack of balance and coordination are his biggest disadvantages. His medical history revealed no corrective surgery to any muscles or tendons, and no medical problems concerning his health. He uses Livoston (WADA approved), a selective histamine H1-receptor antagonist, to provide symptomatic relief of seasonal allergic rhinitis.

From a young age, CS1 has had professional support in the form of physiotherapy, occupational therapy and speech therapy. He participated in no specific sport until he was eight years old. From ages 8-15, he participated in tennis, cricket, track and field and cycling. He competed the first time at the South African National Championships for the Physically Disabled in 1995, in both track and field and cycling. This was at the age of 14. In 1999 at the age of 18, he decided to specialize in cycling. This was also the first year he was selected to represent South Africa at an international competition. His list of achievements at international level is evidence that he is an elite cyclist:

Year	Achievements in Cycling
1999	World Championships - Colorado Springs, USA 7 th position in road race 10 th position in road time trial
2000	Paralympic Games, Sydney - Australia 4 th position in road race 4 th position in road time trial
2001	European Championships - Switzerland 5 th position in road race 7 th position in road time trial

2002	World Championships – Germany Gold in road race Silver in road time trial
2003	European Championships – Czech Republic Gold in road race Bronze in road time trial
2004	Paralympics – Athens Accident in road race, did not finish Bronze in road time trial, combined classes

In order to determine how to support his training, a short summary was made in 2003 of the training methods he used as well as the support system available to him, as part of a needs analysis. The following is a summary of this preliminary information that was used to provide a framework for the development of a strategy to enhance the cycling performance of CS1:

Usual competitions each year	<ul style="list-style-type: none"> • South African National Championships for the Physically Disabled. • South African Cycling Championships (able-bodied). • World Championships / International event. • Fun rides.
Training intensity	No specific monitoring (went out as hard as he could).
Different training modes	Spinning classes and roller training specifically adapted for the tricycle; road training.
Bike Setup	The tricycle is built and set up specifically for him.
Coach	Father.
Coach's qualifications	Self-taught.
Training facilities	Spinning class, rollers, road training.
Professional support	Limited Sport Science support through Stellenbosch University in cooperation with Disability Sport South Africa, when funds were available.

Modifications to CS1's Evaluation and Training

Because training must be customized at the elite level, it is necessary to modify evaluations and interventions to each specific cyclist's needs. The unique happenings in each cyclist's daily life will also modify pre-planned evaluation and training decisions.

Daily Monitoring

Daily monitoring during the first macrocycle from April 2003 - October 2003 was based only on the cyclist's training log. During the other two macrocycles (from October 2003 - October 2004), heart rate monitor data were used to determine intensity, volume (duration in time) and frequency of training. The cyclist's daily training log was used to provide the rest of the data. Heart rate training data were received every Monday, which made continuous monitoring possible.

Physiological Monitoring

This cyclist came for testing after work for all of the evaluation sessions, except the evaluation session in July, 2004 when he was tested at the training camp. The following modifications were made to the general evaluations:

1. Anthropometry.

No modifications were necessary from those described previously.

2. Wingate test.

CS1 was tested on a Monark ergometer against a resistance of 7.5 % of body mass for the first two test sessions. This resistance was changed at the October testing to 9.8 % of body mass, due to an increase in leg power. The rest of the protocol stayed the same.

3. Incremental test to exhaustion.

The following testing protocol was used:

Start load: 130 Watts.

Increments: First increment 30 Watts, thereafter 20 Watts.

Duration of increments: Each increment was 150 seconds.

4. 1-hour distance trial.

No modifications.

5. 1 km & 3 km time trial.

CS1 did not do this test because there are no track events for tricycles.

6. 7.5 km time trial.

CS1 used a two-wheel bicycle that has the same set-up (same bicycle, just a two-wheeler not a three-wheeler) as his tricycle. The bicycle was therefore customized for him. The rest of the test followed the standard protocol.

Individual Interventions

Individual interventions included providing CS1 with training programmes and weekly contact, which fulfilled both an informational and motivational role.

Group Interventions

The cyclist attended both group interventions (as described in Chapter Three).

Physiological Monitoring First Macrocycle: April, 2003 – October, 2003

During the first consultation meeting with CS1, the nature of the research project was explained. CS1 expressed enthusiasm for participation and signed an informed consent form (see Appendix A). A short needs analysis regarding his access to coaching, different training modes, training programmes, and use of goal-setting was made.

The First Macrocycle was set from the South African National Championships for the Disabled held in April, 2003 to the European Championships in September, 2003. This macrocycle was 26 weeks long, with a double peak period for the two competitions.

Direct Factors Targeted during First Macrocycle

The research question guiding this study focused on the management of selected direct factors important for sport performance for elite cyclists with cerebral palsy. The following direct factors were identified and managed in the following way:

1. **Performance Assessment:** Due to the nature of this cycle, the competition performance was evaluated for CS1 in April 2003; June 2003 as well as October 2003. Performance assessment in the laboratory was done one week post competition.
2. **Periodised Planning of Training:** Before the study no periodised training planning took place. CS1 received an in-depth training plan according to the physiological goals for this session.
3. **Feedback on Training:** This was introduced to CS1 for the first time in his career. Explanation of how to complete the training log after training each day was given. The training log was important to evaluate the volume as well as duration CS1 was used to training.
4. **Training Sessions:** The training modes available to CS1 were road cycling, spinning, and roller trainers with no resistance. Each training session was planned for CS1.
5. **Training Camps:** A short training camp was the first encounter with CS1. The study was explained as well as the importance of a training log, periodisation of training and different training techniques to develop an all round cyclist.
6. **Sports Medicine services and products:** No funding available for support in this macrocycle.

Goals for the First Macrocycle

The primary goal for the first macrocycle was to prepare for the European Cycling Championships for Persons with Disabilities in Prague, Czech Republic, in September, 2003. During this period, CS1 also wanted to peak for the South African Cycling Championships that was held in June, 2003, as part of his preparation for September. The macrocycle was therefore divided into two peaks, with all training phases included in the buildup for each peak period. The physiological goals was to improve CS1's cardiovascular endurance, and then to improve his power.

Physiological Evaluations

All three assessments were done at competition time (April 2003 SA National Championships for the Physically Disabled; June, 2003 SA Cycling Championships; October, 2003 European Cycling Championships for Persons with Disabilities). Due to his double peak periodisation, it was decided to evaluate the effect of training the first week after each competition. The laboratory test results are presented below.

Anthropometry

Table 12 is a summary of the anthropometric measurements for CS1 during the First Macrocycle.

Table 12. Anthropometric measurements of CS1 (First Macrocycle)

Date	April 2003	July 2003	October 2003
Age (yr)	22	22	22
Body mass (kg)	66.6	65.2	65.3
Height (cm)	172.6	171.5	172
% Fat	10.8	11.1	10.9
Somatotype	2.6 -4.7 – 2.6	2.5 – 5.0 – 2.6	2.3 - 4.7 – 2.7

Body mass CS1 lost 1.4 kg from April to July 2003, but his body mass stayed stable through the October session.

Height CS1's height varied a bit between the three test sessions. This could be due to his disability. CS1 has some involuntary movements due to the cerebral palsy and it is not always possible for him to stand totally erect. The same test administrator and test apparatus were used in each session, and all the testing was done in the evening, after working hours.

Fat percentage Although CS1 lost some Body mass between April and June, his fat percentage changed by 0.3 %. His fat percentage changed again in October, but his body mass stayed constant.

Somatotype The endomorphy and ectomorphy components stayed nearly constant throughout this phase. The mesomorphic component increased from April (4.7) – June (5.0), but returned to 4.7 during October.

Summary CS1's anthropometry values stayed more or less constant during this phase. His fat percentage could decrease a bit, which could be beneficial for performance. A fat percentage between 8 -10 % body fat is recommended for cyclists (Lucia et al., 2001).

Incremental Exercise Test to Exhaustion

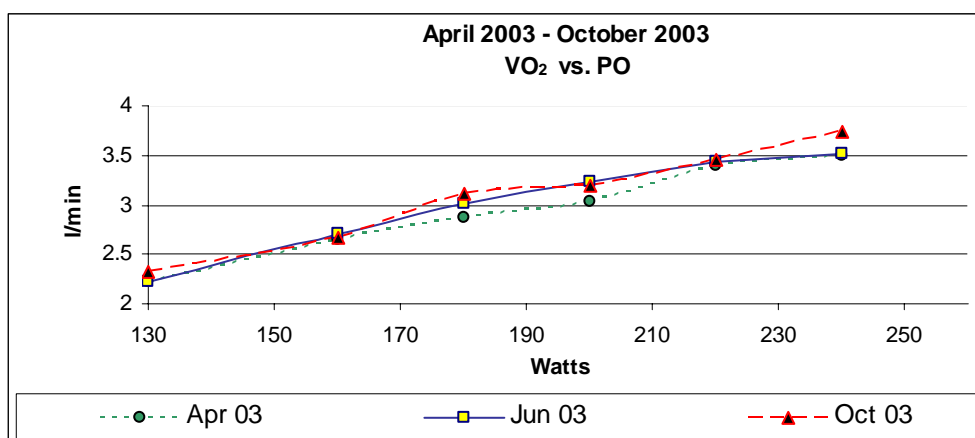
The results of this test are presented in Table 13.

Table 13. Results of the incremental exercise test to exhaustion for CS1 (First Macrocycle)

	April 2003	June 2003	October 2003
Total time of test (min:s)	14:15	14:21	15:00
VO ₂ max (l/min)	3.49	3.51	3.73
VO ₂ max (ml/kg/min)	53.1	53.3	57.2
HR _{max}	181	179	179
Peak power output (PPO) (Watts)	233	235	240
PPO / body mass (W/kg)	3.50	3.60	3.66
Max lactate (mmol/l)	9.2	7.2	9.6
La ₂ (Watts)	Rest	130	170
La ₂ (HR)	Rest	131	150
La ₄ (Watts)	180	187	182
La ₄ (HR)	160	160	162
Maximum RER	1.13	1.14	1.04
RER of 1 (Watts)	180	180	200
RER of 1 (HR)	168	169	162
Time cycled at RER above 1 (min:s)	6:45	6:52	5:00

Graph 2 illustrates the efficiency of pedaling expressed as the relationship between oxygen used and work done (watts of pedaling).

Graph 2. Pedaling efficiency for CS1 (First Macrocycle)

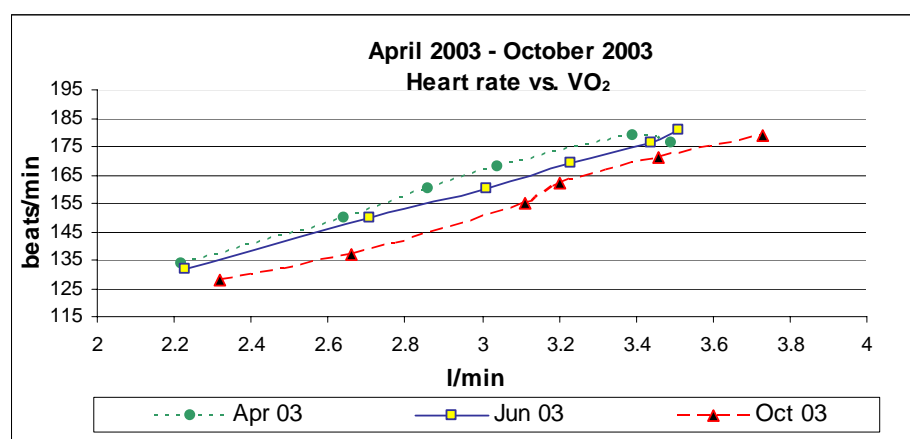


The maximal oxygen uptake is the body's capacity to transport and utilize oxygen during exercise (Powers & Howley, 2001). There is a linear relationship between VO_2 and power output (PO).

- In April, CS1 was cycling at a lower VO_2 at the 3rd and 4th workload compared with June and October. This indicates that his pedaling efficiency was better. The area of greatest difference in pedaling efficiency was between workloads 180 Watts – 200 Watts.
- Differences of less than 1 % in VO_2max and PPO were seen in June. Pedaling was less efficient than in April.
- In October, his maximal VO_2 was a 7 % improvement on the maximal VO_2 in April. The power (watts/kg), of CS1 increased from April to October by 4.6 %.

Graph 3 illustrates the relationship between heart rate and oxygen uptake (VO_2).

Graph 3. Heart rate for CS1 (First Macrocycle)



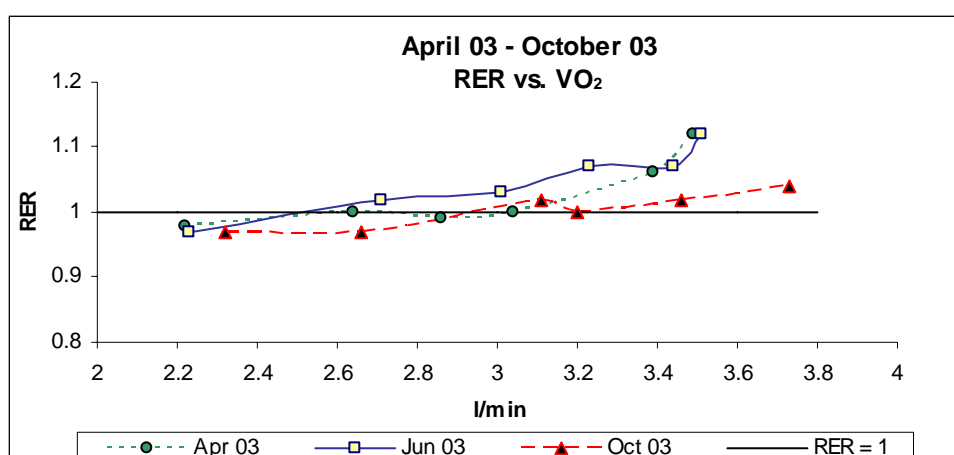
Maximal oxygen uptake is seen as the product of cardiac output and arterial-mixed venous oxygen difference (Powers & Howley, 2001). Cardiac output is the product of heart rate and stroke volume.

- A linear increase in heart rate to a HR_{max} of 181 bpm in April was achieved. Heart rate was less efficient during April than June, or October.
- The maximum HR of CS1 changed from 181 bpm in April to a maximum of 179 bpm in June and October. Heart rate efficiency improved slightly from April to June.

- CS1's heart rate relative to VO_2 in October was lower at all levels of VO_2 than in either June or April. The change ranged between 4 and 13 bpm at various levels of oxygen utilized. A lower heart rate at each VO_2 indicates a better physiological adaptation to endurance exercise.

Graph 4 presents the relationship between the respiratory exchange ratio (RER) and the oxygen uptake (VO_2). RER indicates the estimated contribution of carbohydrate and fat to energy metabolism during exercise. It is the ratio of carbon dioxide output (VCO_2) to the volume of oxygen consumed (VO_2) (Powers & Howley, 2001).

Graph 4. Respiratory exchange rate for CS1 (First Macrocycle)



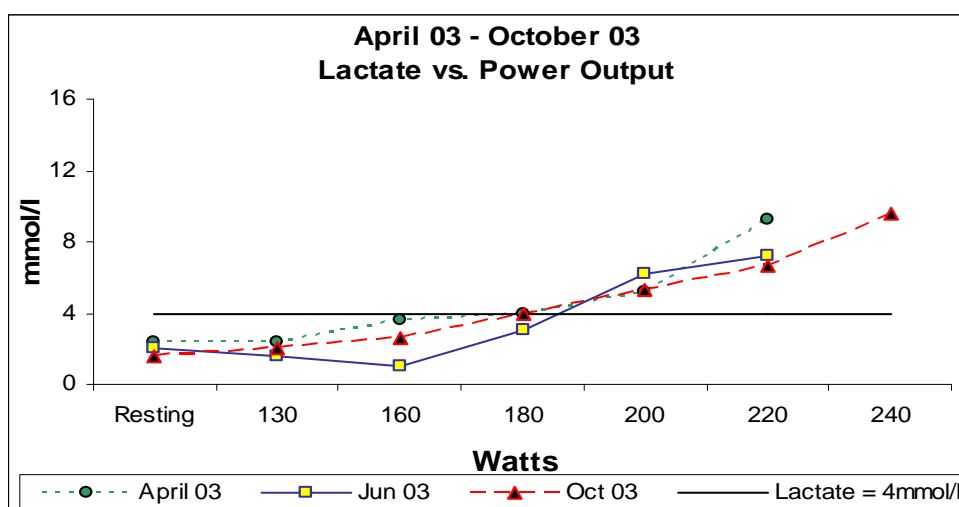
An RER under 1 indicates a desirable level in CS1's capacity to use fat oxidation to produce energy for the cycling action. A lower RER indicates greater fat vs. carbohydrate oxidation. In contrast, an RER above 1 indicates hyperventilation associated with anaerobic metabolism and fatigue.

- An RER of 1 was achieved at 180 Watts during April and a heart rate of 168 bpm. A maximum RER of 1.13 was achieved in April.
- The testing in June was an indication that CS1's training programme needed to be modified to incorporate training that would support a greater use of fat oxidation as energy source. An RER of 1 was achieved at 180 Watts and a heart rate of 169 bpm.
- The testing in October was an indication that CS1 had a good capacity to cycle aerobically, but was not able to push himself into the anaerobic zone at the end of the test. The testing in October was after a competition, and "tired legs" could have made

it difficult to demand great amounts of energy from the anaerobic system, thus resulting in low RER values at the final workload. However, RER appeared to be lower at several other workloads, indicating a greater capacity to oxidize fat as fuel. An RER of 1 was achieved at 180 Watts for April and June, but during October, CS1 reached an RER of 1 at 200 Watts.

Graph 5 is an illustration of blood lactate concentrations (mmol/l) at each workload (Watts) during the incremental test.

Graph 5. Blood lactate accumulation for CS1 (First Macrocycle)



A shift of the lactate graph to the right is a good predictor of improved performance (Faria, Parker & Faria, 2005; Janssen, 2001). A lower lactate value at a specific workload indicates a better physiological adaptation to that work intensity, except during overtraining (Jeukendrup & Hesselink, 1994). Various explanations have been offered for this relationship (Gladden, 2004). A lower lactate value at a workload is indicative of improved endurance performance. During this study, the onset of blood lactate accumulation (OBLA) at 4 mmol/l was used to monitor improvement, this was calculated by extrapolation. La at rest was taken before warm-up.

- OBLA was achieved at 77% of PPO (233 Watts) during April.
- OBLA was achieved at 80% of PPO (235 Watts) in July.
- OBLA was achieved at 75.8% of PPO (240 Watts) in October, due to the improvement in PPO.

The Watts at which the different graphs cut the 4 mmol/l line indicate that endurance performance seemed to have improved, with June being the best. At higher intensities, CS1 was better prepared in October.

Discussion of Incremental Exercise Test for CS1 (First Macrocycle)

Peak aerobic power output is the maximal sustained power a cyclist can produce during an incremental exercise test and is seen as a good performance indicator (Faria et al., 2005). The slight improvement of $\pm 3\%$ in peak aerobic power is therefore an indication that the training programme did contribute to improved performance. Jeukendrup & Martin (2001) summarized studies on the effect of training on peak power output and $VO_2\text{max}$ of trained cyclists. The range of improvement in PPO was found to be between 2.4 – 5%. Improvements in moderately trained cyclists' $VO_2\text{max}$ ranged between 5.5 & 7% after 4 weeks and 8 weeks of training intervention respectively (Jeukendrup & Martin, 2001). The increase in $VO_2\text{max}$ for CS1 was in the range for trained cyclists.

The heart rate graph indicates that the training during this phase resulted in continuous improvements in the cardiovascular system, by either improving the heart's capacity to pump more blood (SV) or the efficiency of the muscles to extract oxygen during cycling.

The shift of the lactate graph in June to the right, indicates that the training before June had a positive effect on the capacity to reduce lactate accumulation at a resistance between 130-180 Watts. Training between June and October had a positive impact on blood lactate accumulation at higher resistances between 180-200 Watts. The higher lactate values at the lower workloads indicate that lower intensity training was not conducted properly to allow adaptations at lower PO, probably because distance training was insufficient.

Wingate Test (sprint power and resistance to fatigue)

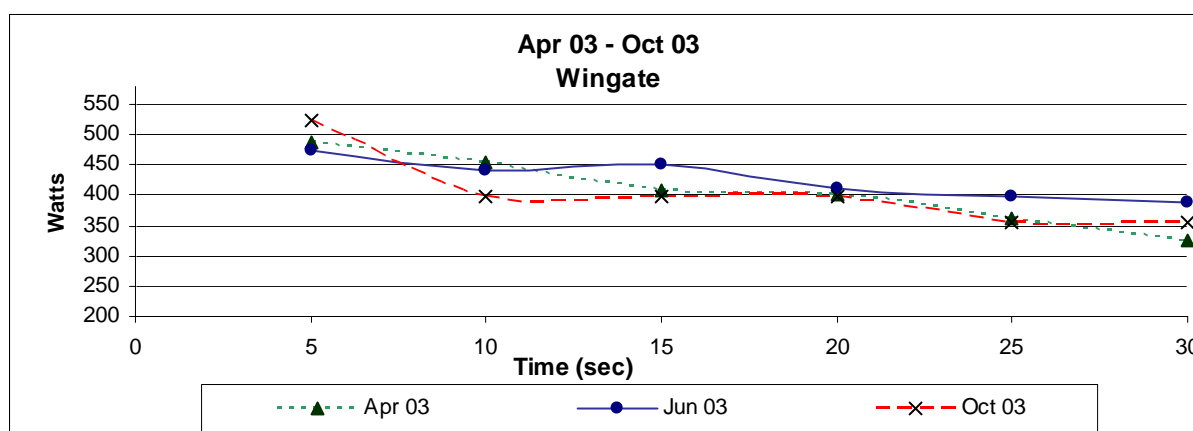
Results of the 30 second Wingate test are presented in Table 14.

Table 14. Values obtained from the 30 second Wingate test for CS1 (First Macrocycle)

	April 2003	July 2003	October 2003
Resistance	7.5 % / BW	7.5 % / BW	9.8 % / BW
Body mass (kg)	66.6	65.2	65.3
Peak sprint power (Watts)	489	474	524
Relative peak sprint power (W/kg)	7.4	7.2	8.1
Avg sprint power (Watts)	406	427	405
Avg relative sprint power (W/kg)	6.2	6.5	6.2
Minimum sprint power (Watts)	325	387	354
Avg sprint power/ peak sprint power %	83 %	90 %	77 %
Fatigue index (W/s/kg)	0.08	0.04	0.09

Graph 6 is an indication of the average power output (Watts) during each 5 seconds of the Wingate test.

Graph 6. Sprint power and resistance to fatigue for CS1 (First Macrocycle)



Improved anaerobic sprint power is important for tactical attacks in the race on the road where power is needed over a short period of time.

- June assessments showed that CS1's peak sprint power did not improve but his average sprint power did. His average sprint power improved by 5 %, despite a small decline in peak power (3 %).

- His peak sprint power was the highest during October, with a 7 % increase from April. The change in test protocol from a resistance of 7.5 % of body mass to 9.8 % of body mass makes it difficult to compare these results. Higher workloads result in higher power outputs (Bediz, Gokbel, Kara, Ücok, Cikrikei & Ergene, 1998).

When body mass is taken into account, the relative sprint power output increased with 8.5 % from April to October. For uphill climbing where body mass plays a role, relative sprint peak power output is important. The increase in relative peak sprint power output indicates that the training did improve CS1's leg power. The % peak sprint power output maintained over average sprint power output is an indication of CS1's capacity to sustain peak sprint power. In June, the peak sprint power output was the lowest but the mean power was the highest in this macrocycle and therefore a better fatigue index was achieved.

1-Hour Distance Trial

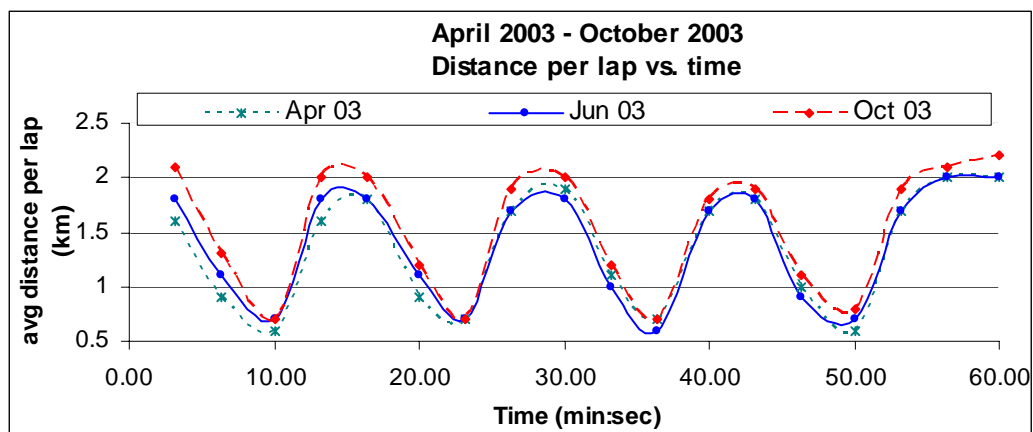
The results of this test are presented in Table 15.

Table 15. Values obtained during 1-hour distance trial for CS1 (First Macrocycle)

	April 2003	June 2003	October 2003
Total distance (km)	24.7	24.9	27.6
Avg cadence (rpm)	74 ±13	75±11	80±13
Total distance 4 % Incline (km)	4.9	4.1	4.8
Avg cadence 4 % Incline (rpm)	64±5	69±4	76±4
Total distance 8 % Incline (km)	2.6	2.7	2.9
Avg cadence 8 % Incline (rpm)	57±1	58±6	61±2
Avg heart rate (bpm)	149±15	161±9	159±9
Highest heart rate (bpm)	176	176	171

Total Distance. Graph 7 illustrates the average split distances per lap over time. The peak distances were during the flat part of the race and the shorter distances during the hill climbs. Motivation and a learning effect can play a role in this test.

Graph 7. Lap distance (km) during 1-hour distance trial for CS1 (First Macrocycle)



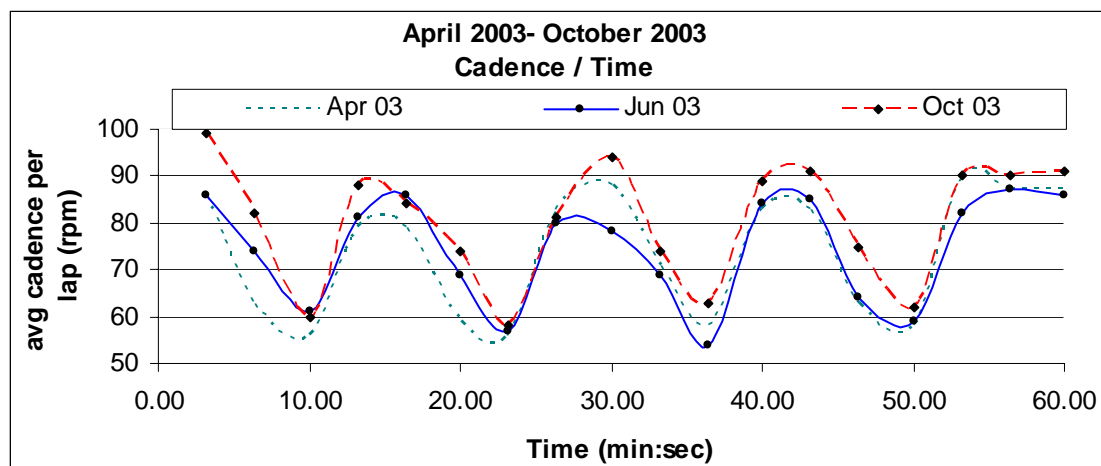
(Rationale for connecting the data points was presented in Chapter Three.)

The graph indicates the distance covered per lap. Lap time is equal to 3:20 (min:s). To simplify the interpretation of this graph, it should be remembered that the first lap was flat, the second was a 4 % gradient climb and the third an 8 % gradient climb, followed by 1 more flat lap. This sequence was repeated four times with two extra sprint laps at the end.

- Table 22 indicates a 0.2 km change in total distance in June, but with a -0.8 km change on the 4 % hill, and a 0.1 km change on the 8 % gradient hill. This indicates that CS1 cycled with slightly different tactics on the flats to increase his distance. Looking at Graph 7, it can be seen that this occurred only in the first lap.
- The greatest total distance covered in this macrocycle was during October (an 11.7 % increase in distance from April's). The total distance covered over the four 4 % gradient hills in October was still 0.1 km less than in April, but 0.7 km better than in June. The total distance for the four 8 % gradient hills in October was 0.3 km more than in April and 0.2 km more than in June. This indicates that out of the additional 2.9 km CS1 covered in the October test, 0.2 km was from the hills and 2.7 km were from the flat terrain. From June to October, a 2.7 km increase in distance was recorded, with 900 m on the hills and 1.8 km on the flat. This indicates that the CS1's capacity to recover after the hills had improved, which allowed him to cycle faster on the flat terrain as well as improve his climbing capacity. The pacing strategy used by CS1 allowed for a final sprint in the last 2 flat laps (also fastest in October).

Cadence (rpm). Graph 8 is an illustration of the cadence (rpm) averaged for each lap over the period of time. The cadence was higher on the flat part of the race and lower on the hills.

Graph 8. Cadence (rpm) selection during 1-hour distance trial for CS1 (First Macrocycle)



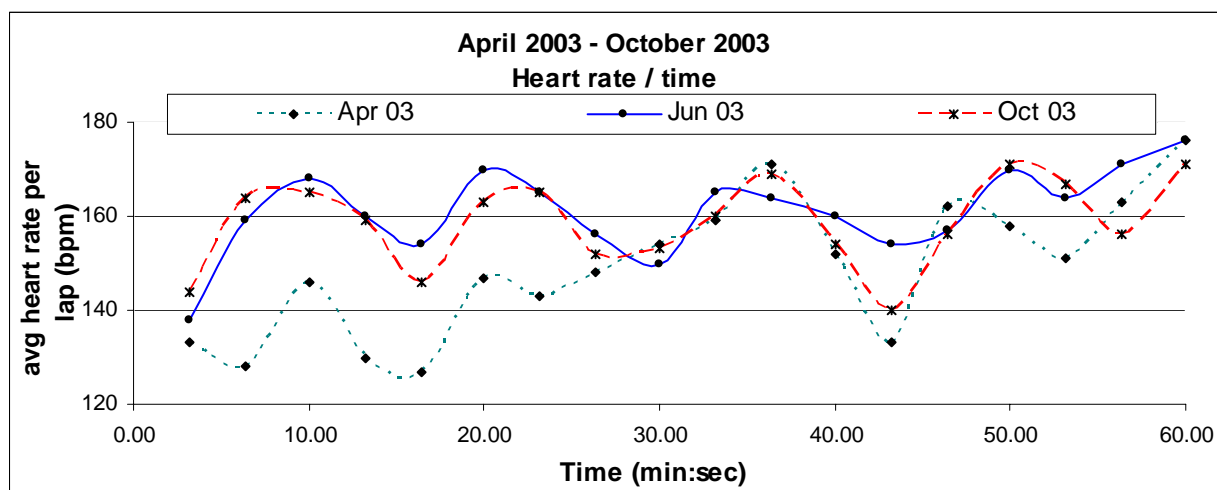
(Rationale for connecting the data points was presented in Chapter Three.)

- During June, the average cadence of 75 rpm did not differ from April, but on the 4 % gradient hill the average cadence of 69 rpm was slightly faster.
- CS1's capacity to cover a longer distance during October was associated with an change in cadence on the flats, as well as on both hills. The average cadence CS1 maintained during October was 80 rpm. The average cadence used during the hill climbing in October was 76 rpm for the 4 % gradient hill but still only 61 rpm for the 8 % gradient hill. This indicates that CS1 achieved a greater distance in one hour by using a higher average cadence, mainly on the flat and 4 % gradient.

Higher average cadence is not always an indication of greater speed because gear selection affects cadence. However, the faster speed during this test could have been the result of the capacity of CS1 to maintain a higher cadence. Higher cadence at high intensity requires more muscle endurance than a higher cadence at lower intensities, due to increased demands for muscle recruitment.

Heart Rate (bpm). Graph 9 illustrates the heart rate (bpm) averaged per lap over the time period of the test.

Graph 9. Heart rate (bpm) during 1-hour distance trial for CS1 (First Macrocycle)



* HR max for incremental exercise test = 181 bpm.

(Rationale for connecting the data points was presented in Chapter Three.)

- The average heart rate for April was 149 bpm, which means that CS1 cycled on average at 82 % of HR_{max} . The highest heart rate of 176 bpm during the distance trial did not reach the HR_{max} as defined from the incremental test to fatigue.
- Average heart rate increased to 161 bpm in June. This is 89 % of heart rate max and indicates an increase in physiological intensity despite no change in distance.
- The average heart rate for October was similar to June, despite improved distance covered. The average heart rate represented 88 % of HR_{max} .

The heart rate graph indicates that CS1 did not start at such a high intensity in April compared to either June or October. This was not because he was unfamiliar with the test because a familiarization test had been done. Rather this indicates that his pacing strategy improved with experience possibly his confidence increased. Another important point to notice is that heart rate fluctuated with the terrain, so that higher heart rate was seen as speed decreased on the gradients. But the flats were used by CS1 to recover. The average HR achieved during June and October was within one beat of the La_4 HR measured during the incremental exercise test. The inability of CS1 to cycle at a higher percentage of HR_{max} in April could be indicative of either a lack of high intensity training or motivation.

Summary of the 1-Hour Distance Trial. Of interest is the fact that the heart rate values during the hill climb for June and October were close to the same, but the heart rate recovery after the hills was better in October. One might think that the lower heart rate might have been associated with less speed on the flat terrain, but as the distance graph indicates that speed actually improved. This increased ability to recover can be seen as an important factor in performance improvements. The higher cadence chosen could also have played a role. Although more research is necessary to determine the optimal cadence for a cyclist with cerebral palsy, it is known that high cadence at higher resistance is more efficient than lower cadence (Takaishi et al., 1996). However, if the cyclist is a “power rider,” he may prefer lower cadences than a rider who has less power, but has an increased aerobic capacity. CS1 shows a tendency to be better prepared aerobically rather than having the power, and the result of a better distance at a higher cadence can be due to this.

Coordination is a problem with cerebral palsy, but his cerebral palsy is not spastic and co-contraction might not have had a big influence on his ability to cycle at high cadence. But if there had been a difficulty in coordination, high cadence will have a greater negative effect than lower cadences (Neptune et al., 1997). When one takes the HR values into consideration, it is interesting that the distance covered in April is only 0.2 km better than in June, but the average HR increased with 12 beats. This means that during June, CS1 needed to work harder aerobically to achieve the same result. While a difference in average heart rate of 2 bpm between June and October indicates the same physiological intensity, CS1 was able to achieve a better distance.

7.5 km Time Trial

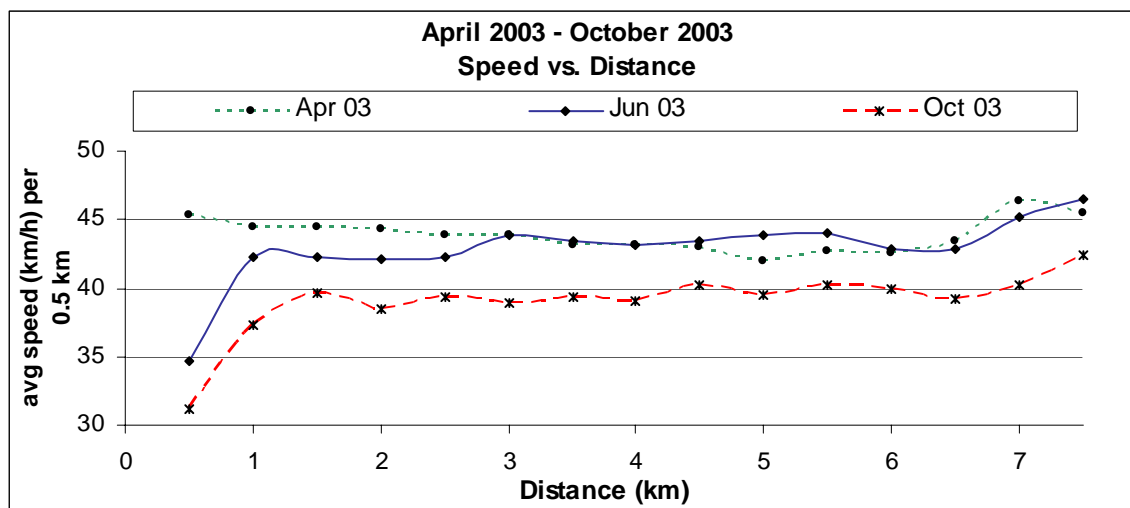
Results of the 7.5 km time trial are presented in Table 16.

Table 16. Results during the 7.5 km time trial for CS1 (First Macrocycle)

	April 2003	June 2003	October 2003
Time (min:s)	10:30	11:29	11:38
Avg cadence (rpm)	102±4	103±4	98±6
Avg speed (km/h)	43.9±1	42.8±3	39±2
Avg heart rate (bpm)	168±4	157±5	159±5
Highest heart rate (bpm)	181	169	168

Time / Distance. Graph 10 illustrates the speed (km/h) averaged per lap achieved up to the distance (km) during the 7.5 km time trial, which provides insight into the time trial capacity and tactics used by CS1.

Graph 10. Average Speed (km/h) during 7.5 km time trial for CS1 (First Macrocycle)



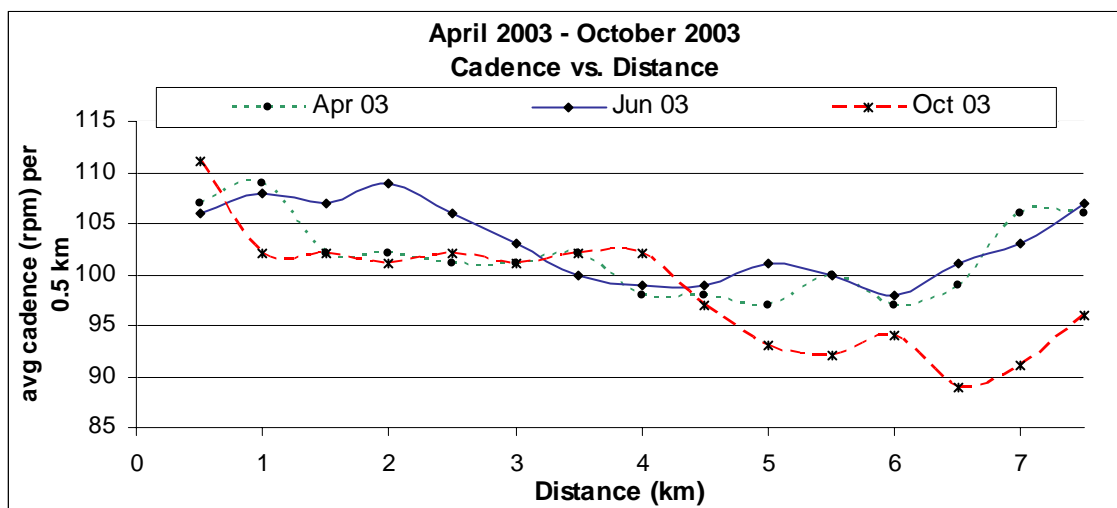
(Rationale for connecting the data points was presented in Chapter Three.)

- The best time of 10:30 (min:s) achieved was during April. The tactic used by CS1 was to go out as fast as possible from the start. The main difference was his average speed over the first three kilometers. The speed in April was constant during the middle part of the race and he picked-up speed over the last 1.5 km.
- When one compares this with the other two races, a gradual increase in pace is seen in June a good average speed during the middle part of the race and a good increase in speed towards the end.
- During the middle part of the October trial, CS1 was not able to achieve the same speed as he did during April and June. June results showed the same pick-up in speed during the last 1.5 km as in April, but the increase in speed for October was lower.

The main difference between April and June was the starting speed. This supports the observation that tactics play an important role in a time trial. CS1's ability to maintain speed and use appropriate tactics was the best during April.

Cadence. Graph 11 illustrates the cadence (rpm) averaged during the time period of the 7.5 km time trial.

Graph 11. Cadence (rpm) selection during 7.5 km time trial for CS1 (First Macrocycle)



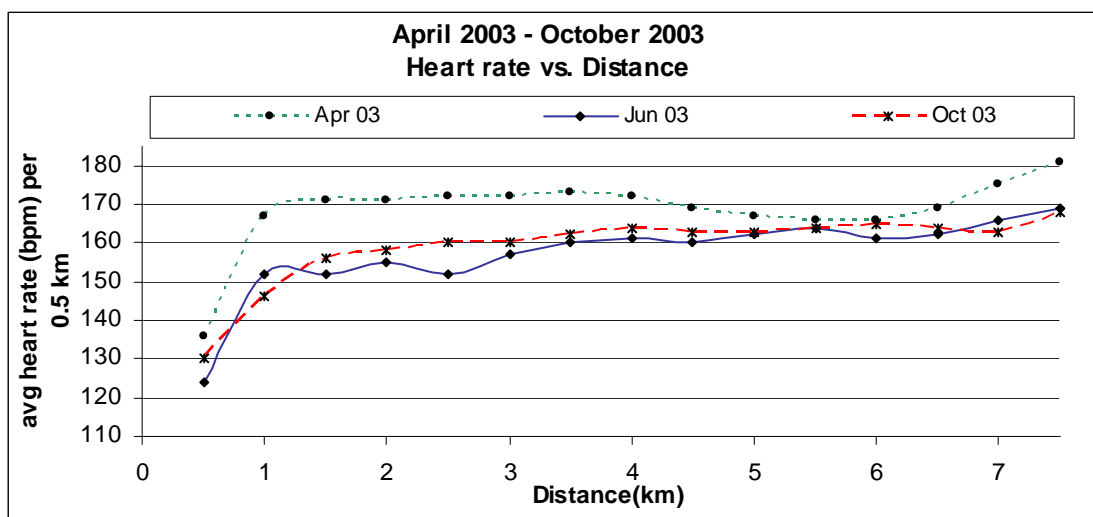
(Rationale for connecting the data points was presented in Chapter Three.)

- The graph illustrates an increase in cadence over the first kilometer in April. During the middle part of the race, an average cadence of close to 100 rpm was maintained. During the last 1.5 km, the cadence picked-up again.
- The average cadences used during April and June were nearly the same (102 and 103 rpm respectively) and the average cadence in October was 98 rpm. The cadence during June indicated a sustained cadence above 105 rpm for the first 2.5 km, after which the cadence dropped to about 100 rpm until the last 1.5 km, when the cadence was increased again.
- During October, a drop in cadence is recorded during the first kilometer. This is maintained until the 4 km mark, after which the cadence just kept getting slower until a cadence of 90 rpm was reached. During the last 1 km, an effort was made to increase the cadence, but it never reached the cadence recorded in April or June.

The fact that no fixed gear selection was compulsory meant that CS1 could change gears as he pleased (change in cadence does not always mean a change in speed). CS 1's ability to increase the cadence towards the end in April indicates good muscle endurance. During races where cyclists need to maintain high power outputs and therefore high oxygen consumption, optimal pedal rates are higher (Coast, 1996). This is the reason for the higher cadence in the 7.5 km than in the 1-hour road race. The race was also flat throughout.

Heart Rate (bpm). Graph 12 illustrates the heart rate (bpm) averaged per 0.5 km over the distance (km) covered.

Graph 12. Heart rate (bpm) during 7.5 km time trial for CS1 (First Macrocycle)



* HR_{max} of incremental exercise test = 181 bpm.

(Rationale for connecting the data points was presented in Chapter Three.)

- The average heart rate achieved during April was 10 bpm faster than during June or October and 93 % of HR_{max} . This effort showed a steeper increase in heart rate over the first kilometer with a heart rate of close to 170 bpm maintained during the middle part of the race. During the last kilometer, the heart rate was elevated to HR_{max} (181bpm).
- The other two trials (June and October) showed the tendency of a lower average heart rate (87 and 88 % of HR_{max}). During the middle part of the trial, average heart rates were close to 160 bpm. The heart rate graph supports the speed graph (the faster trial was performed at the highest heart rate).

Summary of 7.5 km Time Trial. The intensity with which CS1 rode the 7.5 km time trial in April was higher with the obtained HR on average 10 bpm higher than during June and October. This increased intensity was not due to the higher cadence, because the average cadence for June was the same. It can be assumed that CS1 was able to cycle a higher gear at the same cadence to achieve the faster time. He showed more muscle endurance and an ability to sustain 93 % of his maximum heart rate over the duration of the 7.5 km time trial.

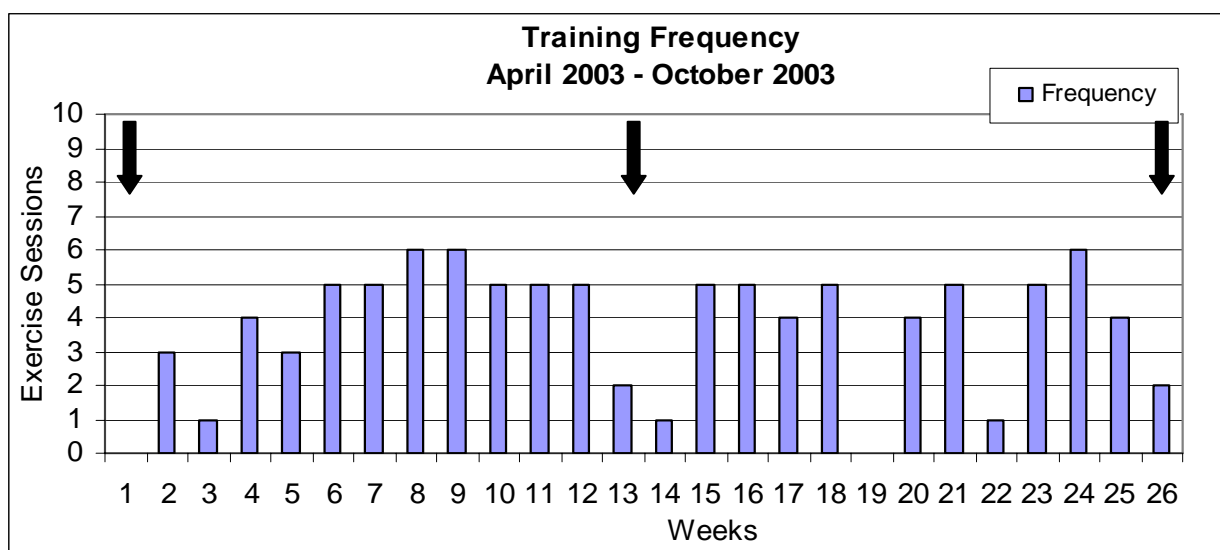
Training

During the First Macrocycle, the training logs of CS1 were used to determine his training intensity, volume, frequency and the mode of training. CS1 bought a heart rate monitor during this period, but various technical problems occurred and the data collected were not always reliable. The decision was made to use only the training logs. It is important to remember that CS1 needed to compete in Week 13 as well as Week 26.

Training Frequency

Graph 13 illustrates the exercise sessions per week for the First Macrocycle.

Graph 13. Training frequency for CS1 (First Macrocycle)



Indicative of competition (testing times were either in the same week or week after)

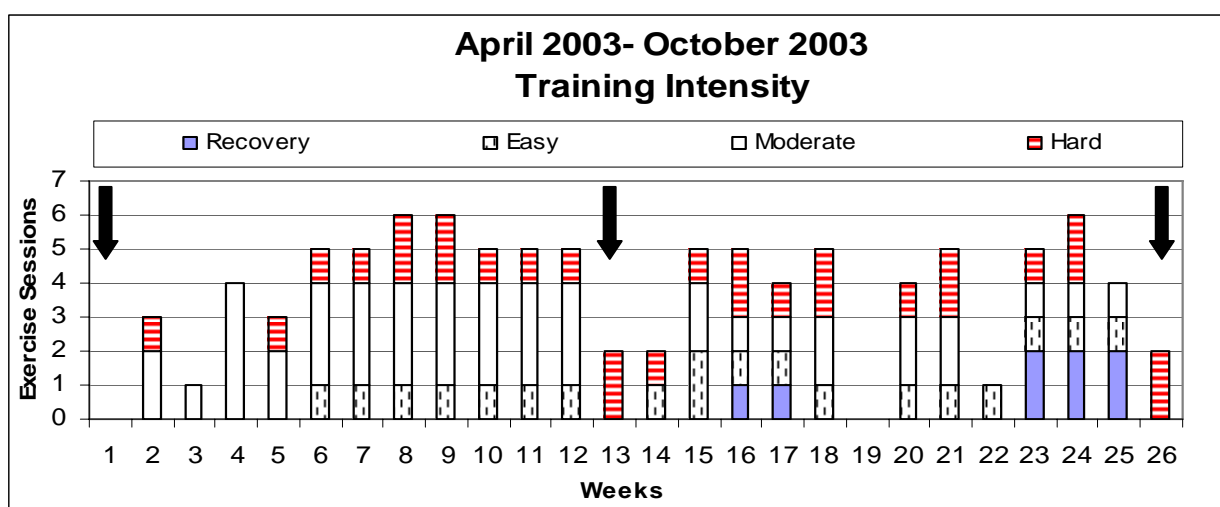
For the body to adapt, it is important to keep training frequency reasonably consistent. Training frequently can be a strategy used to reduce training load for any one session. CS1 was able to train at an average of 5.3 sessions per week for seven weeks prior to Week 13. After Week 13, the sustained frequency of the training sessions varied considerably. There was no training during Week 19 (broken tricycle) and limited training during Week 22 (flu). The competition was held in South Africa in week 13, and a decision was made not to taper for this competition but to see it as part of training for the competition in October.

Training Intensity

CS1 needed to indicate on the training log his perceived effort (rpe) after each training session. The training intensities were then categorized as either recovery (very easy), easy, moderate or hard sessions.

Graph 14 is an indication of the number of sessions done each week and the number of sessions at different training intensities (rpe) during each week.

Graph 14. Training intensity for CS1 (First Macrocycle)



↓ Indicative of competition (testing times were either in the same week or week after)

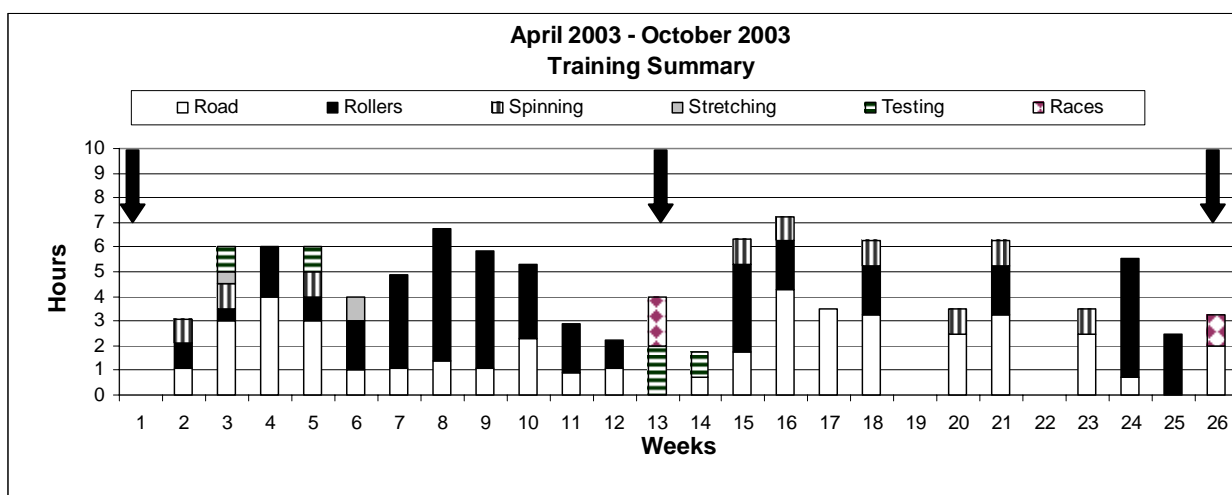
The training before the first competition in Week 13, built-up from being inconsistent (Weeks 1-3) to being consistent in frequency and intensity (Weeks 6-12). The goal of constant training was compromised during the next 13 weeks.

Training Volume and Training Modes

CS1 noted the different training modes he used to do his training in his training log. Training volume (km) was impossible to determine given that he used so many different modes of training, many of which could not be quantified in km. Hence the volume of training is expressed as duration (hours/week).

Graph 15 illustrates the different training modalities used during the First Macrocycle.

Graph 15. Training summary for CS1 (First Macrocycle)



↓ Indicative of competition (testing times were either in the same week or week after)

Prior to Week 13, 50 % of the training volume (26 hr) for CS1 was done on his roller trainer and 38 % of the training volume (20 hr) on the road. Total training volume for Weeks 1 -12 was 53 hours. The reason for the high percentage of roller trainer work was due to the winter weather and early sunsets, which made indoor training more practical. His work commitments made it difficult for him to train before or after work, and the only way to stay fit was either on the rollers or in spinning classes. The rollers are home-made rollers with no resistance. He could not train against high resistance and needed to use his gears and cadence to increase the training resistance. During Weeks 14 – 25 of the First Macrocycle, the training volume was 46 hours (48.6 % of training volume during this cycle was spent on the road, and 36.4 % of the training volume on the roller trainers). The difference in total training volume was 6.7 hours with 2.5 hours more time on the road and 9.6 hours less on the rollers. A lack of competition training before the actual competition was a problem, since competition training is very important for successful bunch riding and practicing tactical decision-making.

General Summary of Training

During the First Macrocycle, the difficulty of training during the winter months on the road was noted as a problem area. The frequency of training of 5 sessions per week seems to be easily accomplished, with 4.4 hours per week training during the first 12 weeks and 3.9 hours of training per week during the second 12 weeks. His frequency of training was good, but the volume of training should have been increased for improved performance and to reach the physiological goal of improved aerobic endurance. The time spent on the road needed to be increased and alternative ways to do high intensity training needed to be found.

Direct Factors Targeted during the First Macrocycle

The research question guiding this study focused on the management of selected direct factors important for sport performance management. The following rating scale reflects the investigator's perceptions of the degree of success in managing these factors.

Direct Factor	Score	Reasons
Performance Assessment	4	CS1 achieved his goals for the competition in June to be selected for the European Championships. His achievement at the European Championships of gold in road race and bronze in time trial speaks for itself. All three laboratory assessments were completed with enthusiasm. Interpretation of the results of the test was difficult in the beginning, due to no normative data against which to compare CS1.
Periodised Planning of Training	3	The training plan was given to CS1, but the implementation was not always good. A broken bicycle and flu were factors to take into consideration. Training feedback was also difficult to interpret due to lack of knowledge regarding training principles for cyclists' with cerebral palsy. The First Macrocycle served as a base of the volume, intensity, frequency and mode of training CS1 was able to do.
Feedback on Training	2	Only basic feedback was given on training logs and the logs were not complete. Time span from end of month to receiving training log was too long.
Training Sessions	3	The implementation of the training programme given to CS1 was not satisfactory. Difficulties in implementation of the programme were factors like weather, early sunset, broken bicycle and lack of time due to working commitments.
Training Camp	4	It served its purpose to explain the importance of planning, as well as the study.
Sports Medicine Services & Products	0	No services due to lack of financial support.

Score = Point out of 5, with 0 not achieved, 5 fully achieved.

Physiological Monitoring Second Macrocycle: October, 2003 - March, 2004

The Second Macrocycle was set after the transition phase following the European Championships in September, 2003, and lasted up to the South African National Championships for the Physically Disabled held in March, 2004.

Goals for the Second Macrocycle

The primary aim for this macrocycle was to prepare for the South African National Championships for the Physically Disabled. The National Championships served as the trials for the South African Paralympic Team for Athens, 2004. It was critical for CS1 to perform at his best at that event. The physiological goal was to improve base endurance during the first part of the cycle and to improve leg power throughout the cycle.

Direct Factors Targeted during the Second Macrocycle

The following direct factors were identified and managed in the following way:

1. Performance Assessment: The only competition evaluation was in March 2004 at the South African National Championships. Performance assessment in the laboratory was done in January after the Christmas holidays and base training period, and the week after the National Championships in March, 2004.
2. Periodised Planning of Training: A periodised plan was given to the cyclist for the first part of the cycle (till the January assessment) that focusing on base training, with the latter part of the cycle focused on high intensity training.
3. Feedback on Training: Training logs were used to gather information about training, and CS1 also bought a heart rate monitor (Polar S720) to provide more specific feedback on training.
4. Training Sessions: The training modes available to CS1 were road cycling, spinning, and roller trainers with no resistance. Resistance training in the gymnasium was an additional mode introduced in the macrocycle.
5. Training Camps: A session by a physiotherapist specializing in cerebral palsy was delivered in this cycle, to improve aspects regarding bicycle set-up and daily living. This session served as a training camp.
6. Sports Medicine services & products: No funding available during the Second Macrocycle.

Physiological Evaluations

The first assessment was completed in January, just after a long period of base training which included Christmas holidays. The second assessment was completed after the South African National Championships for Physically Disabled in March, 2004. The first testing was therefore not at a peak time, but the second was. The results from testing in October, 2003 (same as reported in First Macrocycle) were used to compare with the peak period of March, 2004.

Anthropometry

Table 17 is a summary of the anthropometric measurements for CS1 during the Second Macrocycle.

Table 17. Anthropometric measurements of CS1 (Second Macrocycle)

Date	October 2003	January 2004	March 2004
Age (year)	22	23	23
Body mass (kg)	65.3	66.4	66
Height (cm)	172	172	172
% Fat	10.9	11.7	11
Somatotype	2.3 - 4.7 - 2.7	2.6 - 5.4 - 2.5	2.4 - 5 - 2.6

Body mass CS1's body mass changed by 1.1 kg, in the time period between October and January. Although he did lose 0.4 kg towards competition time, his body mass was still 0.7 kg more in March than in October.

Height CS1's height remained constant.

Fat percentage His fat percentage changed to 11.7 % in January. It changed to 11 % in March.

Somatotype The endomorphy and ectomorphy component of CS1's somatotype stayed nearly constant throughout this macrocycle. The mesomorphic component increased from October (4.7) to January (5.4), but dropped to 5 in March.

Summary CS1's fat percentage and mesomorphic component changed during the base training period before January, 2004. This change in the mesomorphic

component can be due to the long rides CS1 undertook during the base training period prior to January. During this period, strength may have increased (note the slower cadences the cyclist used), which in turn could have produced an increase in muscle mass (training focused on road training at cadence of 70 rpm). Alternatively, more emphasis on road training instead of roller training increased resistance. When high intensity exercise started towards the end of the Second Macrocycle, CS1 lost fat percentage as well as muscle mass, which is reflected in a decrease in his mesomorphic rating.

Incremental Exercise Test to Exhaustion

The results of this test are presented in Table 18.

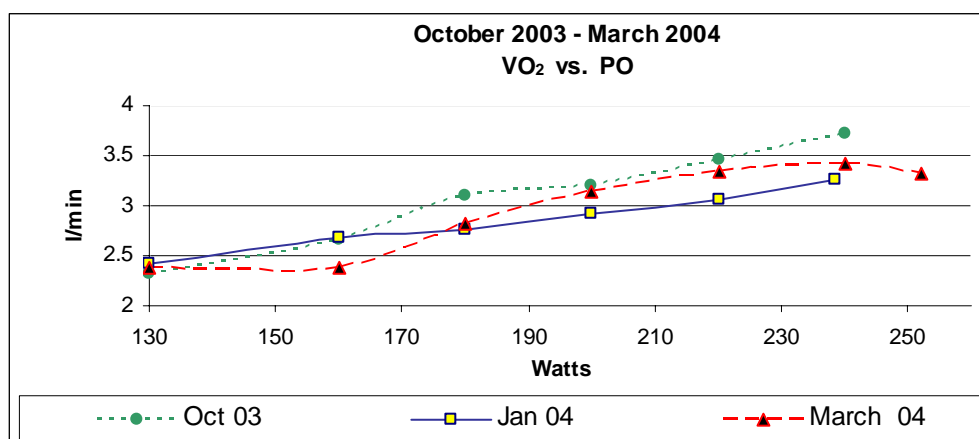
Table 18. Results of incremental exercise test to exhaustion for CS1 (Second Macrocycle)

	October 2003	January 2004	March 2004
Total time of test (min:s)	15:00	14:48	16:35
VO ₂ max (l/min)	3.73	3.26	3.42
VO ₂ max (ml/kg/min)	57.2	49.1	51.9
HR _{max} (bpm)	179	176	181
Power (Watts)	240	238.5	252
Power: body mass (W/kg)	3.66	3.59	3.82
Max lactate (mmol/l)	9.6	5.1	14.2
La ₂ (Watts)	130	Rest	120
La ₂ (HR)	131	Rest	137
La ₄ (Watts)	180	170	185
La ₄ (HR)	160	160	160
Max RER	1.04	1.13	1.09
RER of 1 (Watts)	200	200	220
RER of 1 (HR)	162	166	169
Time cycled above RER 1	5:00	4:40	4:00

The low maximum lactate value and lower HR_{max} might indicate that the January test might not have been a maximum test. This variability in VO₂max might also be contributed by the cerebral palsy and fatigue.

Graph 16 is an illustration of the oxygen cost of pedaling expressed as the relationship between oxygen used and work done (actual watts of pedaling).

Graph 16. Pedaling efficiency for CS1 (Second Macrocycle)

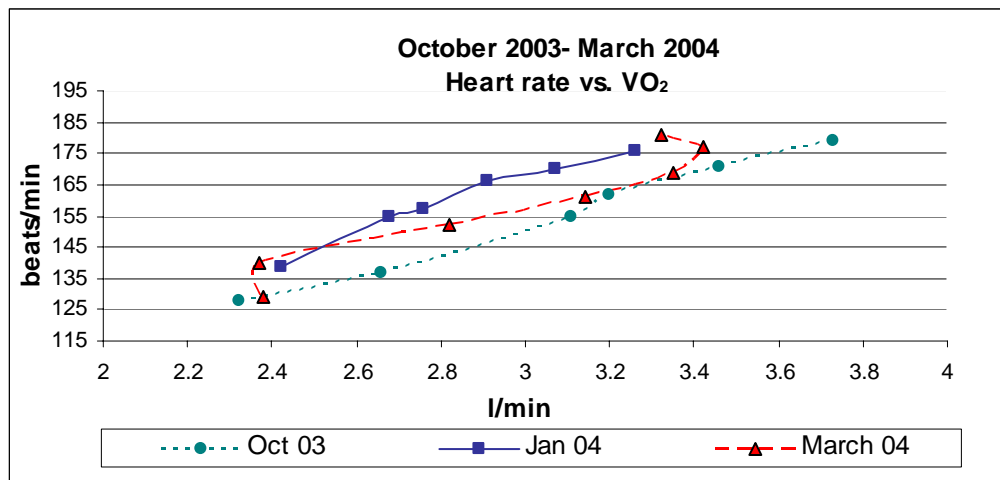


- The October session is the same as the final session presented in the First Macrocycle.
- January results indicated lower values of VO₂ after the 180 Watts point, but higher values before 180 Watts in comparison with March. A decrease in VO₂max from 3.73 l/min to 3.26 l/min is seen in January. PPO was slightly lower in January than in October with 238.5 Watts achieved.
- PPO achieved in March was the highest so far in the study with 252 Watts and a VO₂max of 3.24 l/min. In March, CS1 was cycling at a lower VO₂ up to a workload of 180 Watts. This indicates that the pedaling efficiency of the cyclist was better in March at lower workloads (watts), but in January, pedaling efficiency was better at higher workloads. The peak aerobic power in watts and watts/kg of CS1 changed by 5 % from January to March.

The improved peak aerobic power output is an indication that CS1's training had a positive effect on his sustained power output. Of importance to note is that in January, after the base training, CS1 had nearly the same peak aerobic power as in October. The base training therefore did not produce a decrease in sustained power output.

Graph 17 illustrates the relationship between heart rate and oxygen uptake (VO_2).

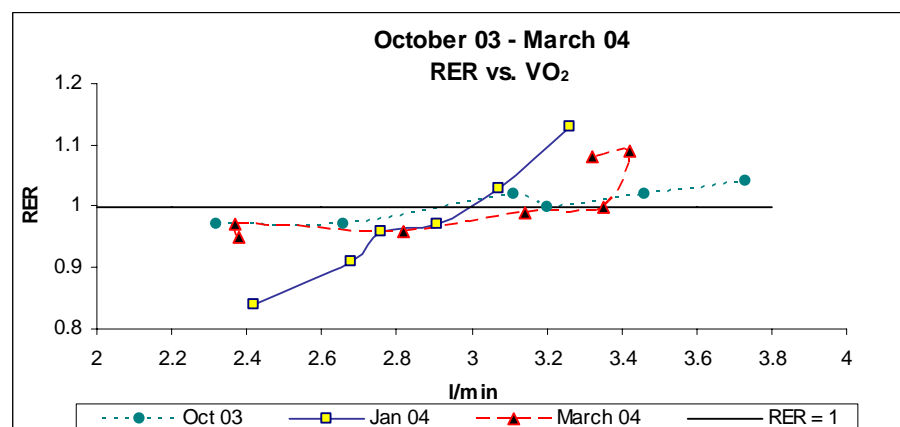
Graph 17. Heart rate for CS1 (Second Macrocycle)



- October shows the most efficient heart rate for a given workload.
- The maximal HR obtained during the January test was 176 bpm, which was lower than in October and March.
- During March, the maximum heart rate was 181 bpm. Graph 17 indicates that CS1's heart rate at each VO_2 in March was lower than in January.

Graph 18 is an indication of the preferred source of energy at the different oxygen uptake levels.

Graph 18. Respiratory exchange rate for CS1 (Second Macrocycle)

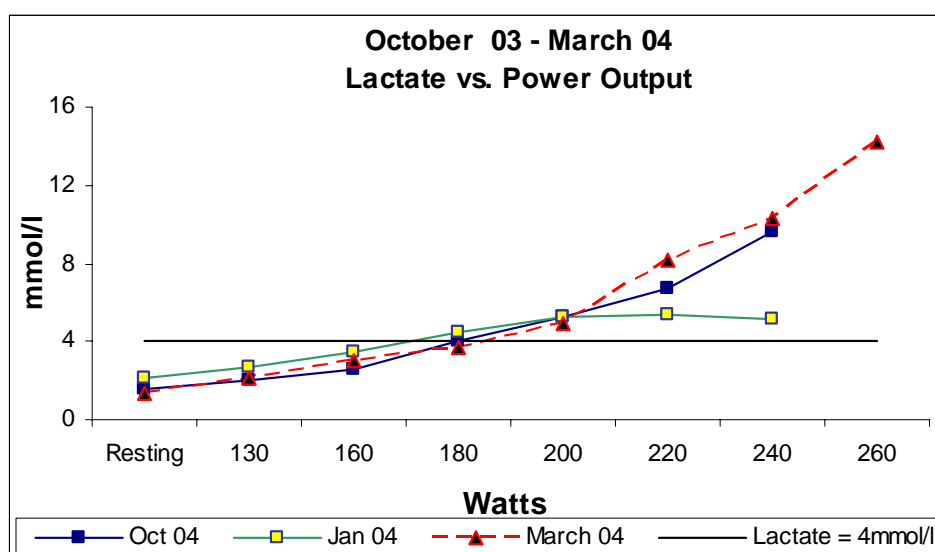


The longer the cyclist can ride under an RER of 1, the better his/her capacity to use oxygen to produce energy for the cycling action without tapping into the anaerobic energy provision to any large extent. The diet was not controlled. The testing in January indicated a very low starting RER, which was an indication that CS1 was possibly glycogen deficient at the time of testing or better adapted to use his oxidative energy system. The latter is unlikely because his VO_2max did not increase.

- October indicates an RER of 1 at 200 Watts and a heart rate of 162 bpm.
- An RER of 1 for January was also at 200 Watts and a heart rate of 166 bpm. However, in January, a steep increase was found in the RER with the RER of 1 between a VO_2 of 2.8 and 3 l/min. The maximum RER in January was 1.13.
- During March, CS1 had an RER of less than 1 up to a VO_2 of 3.4 l/min. This is an indication that his training programme was effective in increasing his capacity to use mainly the oxidative energy system at a much higher intensity. This indicates a capacity to ride at high intensities without using the anaerobic energy system and should minimize fatigue during the race.

Graph 19 illustrates the blood lactate concentrations (mmol/l) at each workload (Watts) during the incremental test.

Graph 19. Blood lactate accumulation for CS1 (Second Macrocycle)



- OBLA was achieved at 75 % of PPO (180 Watts) and a heart rate of 160 bpm, which is at 88 % of HR_{max} , during October. A maximum blood lactate level of 9.6 mmol/l was achieved.
- OBLA was achieved at 71.3 % of PPO (170 Watts) in January. His heart rate at OBLA was 160 bpm (88 % of HR_{max}).
- OBLA was achieved at 73 % of PPO (185 Watts) in March and at a heart rate of 88 % of HR_{max} . His PPO improved as well as his workload at OBLA, which indicates that he was able to ride at a higher intensity without accumulating more than 4 mmol/l of lactate in the blood.

The January results indicate that CS1 was not able to extend himself anaerobically, alternatively the lactate readings were faulty for the last two workloads. Since the lactate values follow similar trends at earlier workloads, the latter explanation is more likely. The La_4 point increased from 170 Watts in January to 185 Watts in March, with the March results showing a steep increase of blood lactate accumulation after 200 Watts. This is indicative that CS1 had adapted to a workload of 200 Watts, but was also able to sustain work at 220-260 Watts despite lactate accumulation, indicating some fatigue was present. When comparing the two competition times (March with October), blood lactate accumulation in October was quite similar to March, except that CS1 was able to push to a higher workload, and thus accumulated more lactate in the final workload in March.

Discussion of Incremental Exercise Test (Second Macrocycle). The slight improvement of ± 5 % in peak aerobic power is sufficient to be an indication that the training programme did contribute to improved performance (Faria et al., 2005) from competition in October to March. The change in VO_2max from 57.2 ml/kg/min to 51.9 ml/kg/min is a slight concern, but the fact that there was a lower VO_2 at each workload in January and March compared with October indicates that while VO_2max decreased, the pedaling efficiency improved.

The heart rate graph illustrates that the training during this phase did not improve the cardiovascular system. Higher heart rates were required in January and March than October, at the same level of VO_2 . The lactate graph shows little variance except for the low lactate values after 200 Watts in January.

Wingate Test (Sprint power and resistance to fatigue)

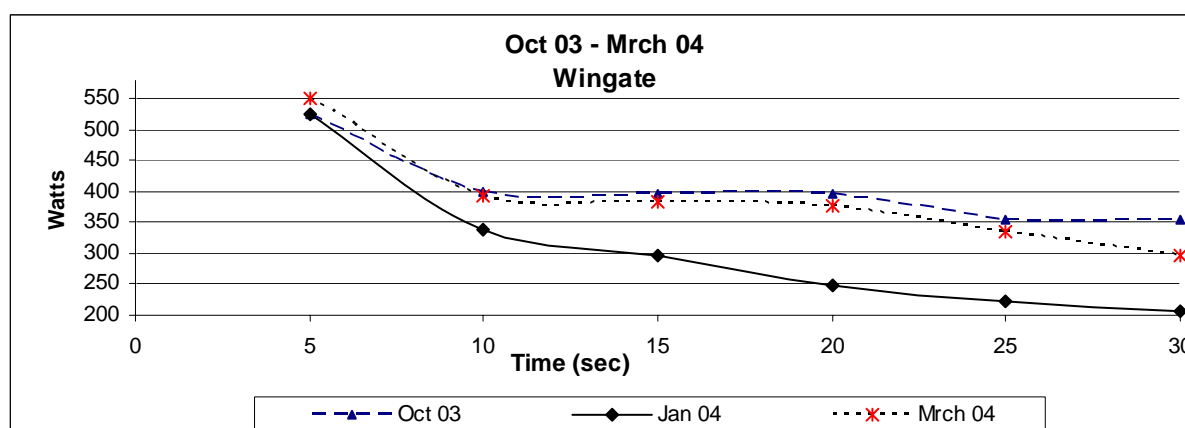
Results of this test are presented in Table 19.

Table 19. Values obtained from the 30 second Wingate test for CS1 (Second Macrocycle)

	October 2003	January 2004	March 2004
Resistance	9.8 % / BW	9.8 % BW	9.8 % BW
Body mass (kg)	65.3	66.4	66
Peak sprint power (Watts)	524	525	550
Relative peak sprint power (W/kg)	8.1	7.9	8.3
Avg sprint power (Watts)	405	307	389
Avg relative sprint power (W/kg)	6.2	4.6	5.6
Minimum sprint power (Watts)	354	208	298
Avg sprint power/ peak sprint power %	77 %	58.5 %	71 %
Fatigue index (W/s/kg)	0.09	0.16	0.13

Graph 20 is an indication of the average power output (Watts) during each 5 seconds of the Wingate test.

Graph 20. Sprint power and resistance to fatigue for CS1 (Second Macrocycle)



- The peak sprint power output during the January Wingate test was similar to October indicating no loss in peak sprint power. However, the ability to sustain the sprint power was reduced compared to October, suggesting greater fatigue.
- The results of the March test showed an improvement compared with January, with good peak and mean sprint power output. Comparing the results of March with October, there was a 5 % change in peak sprint power, but a -4 % change in mean

power sprint output. The increase in peak power indicates a better maximal ability which should translate into improved performance during the first 10 seconds of an attack. The decrease in mean power indicates a weaker ability to maintain peak sprint power over 30 seconds. This is supported by the percentage decrease of the mean power output over peak power output.

When body mass is taken into account, the relative peak sprint power from January to March increased by 5.4 % and the relative mean sprint power by 27.5 %. The increase in mean power indicates an improved capacity to maintain a higher power output.

1-Hour Distance Trial

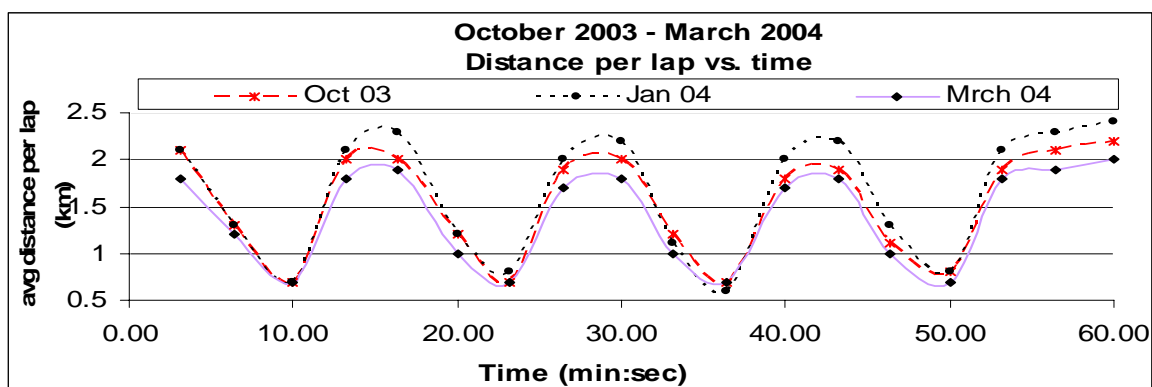
The results of this test are presented in Table 20.

Table 20. Results of the 1-hour distance trial for CS1 (Second Macrocycle)

	October 2003	January 2004	March 2004
Total distance (km)	27.6	29.1	25.2
Avg cadence (rpm)	80±13	81±15	74±14
Total distance 4% Incline (km)	4.8	4.9	4.2
Avg cadence 4 % Incline	76±4	78±2	70±6
Total distance 8 % Incline (km)	2.9	2.9	2.8
Avg cadence 8 % Incline	61±2	58±4	55±2
Avg heart rate (bpm)	159±9	145±6	150±8
Highest heart rate (bpm)	171	156	160

Total Distance. Graph 21 illustrates the average split distances over time. The peak distances were during the flat part of the race and the shorter distances during the hill climbs.

Graph 21. Lap distance (km) during 1-hour distance trial for CS1 (Second Macrocycle)

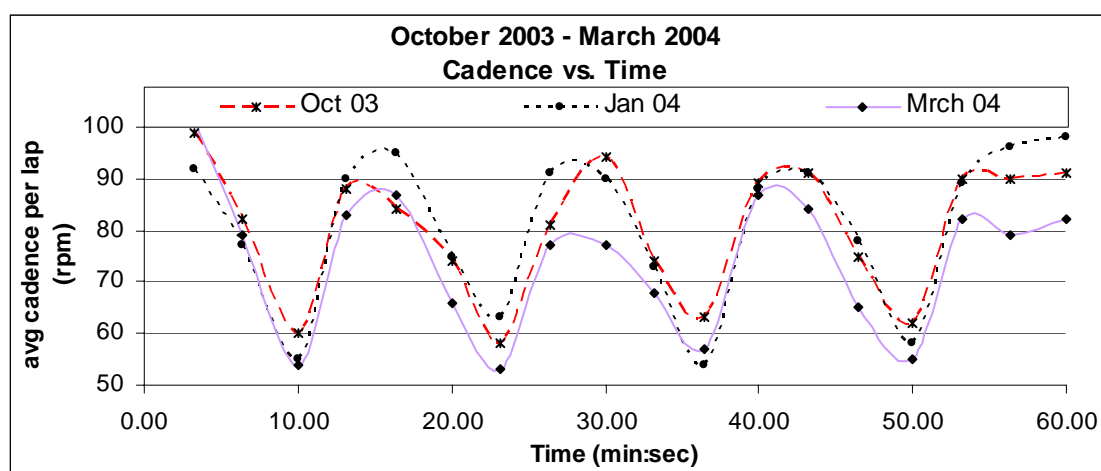


(Rationale for connecting the data points was presented in Chapter Three.)

- The total distance covered during January shows a good improvement (+1.5 km) and a 5 % increase in distance since October. The total distance covered over the four 4 % gradient hills showed a 0.1 km change, but the 8 % gradient hill distance stayed the same (comparing January to October). This means that the improved distance was a change in the distance covered riding the flat parts of the trial.
- The distance covered in March decreased to 25.2 km, with a -0.7 km change from January to March on the 4 % hills and a 0.1 km loss in the 8 % hills.

Cadence. Graph 22 is an illustration of the cadence (rpm) averaged per lap over the Second Macrocycle. The cadence was higher on the flat part of the race and lower on the hills.

Graph 22. Cadence (rpm) selection during 1-hour distance trial for CS1 (Second Macrocycle)

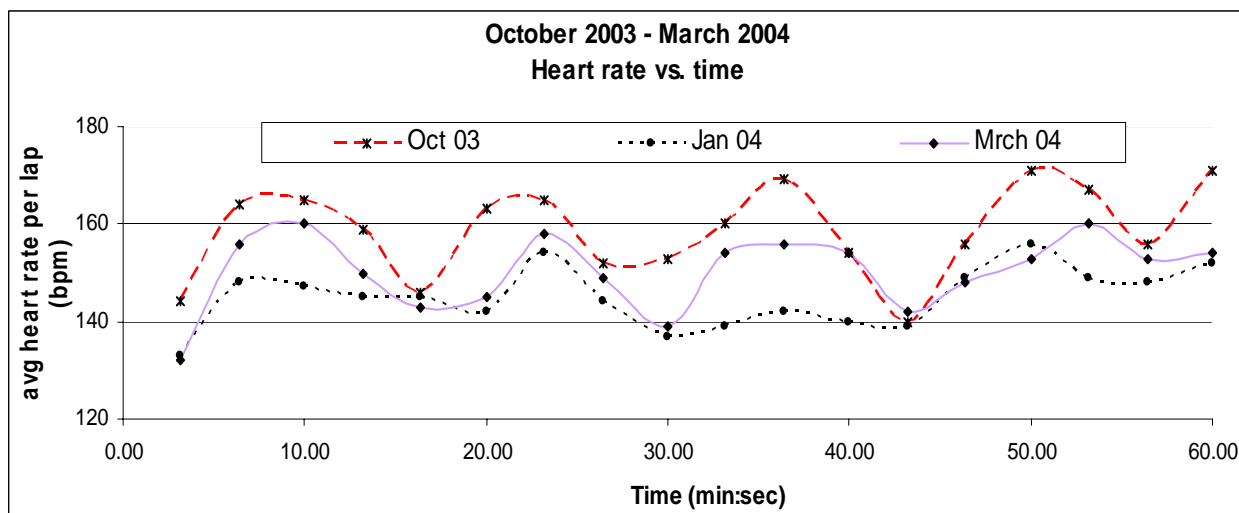


(Rationale for connecting the data points was presented in Chapter Three.)

- CS1's ability to cover a longer distance during January may have been related to an increase in cadence between 10 – 30 minutes, which includes two flat parts. The average cadence over the last 10 minutes of the test was also much higher than during either March or October. The distance covered during January was the best ever achieved, and the cadence on the flats and the 4 % hill was the highest during this macrocycle.
- The cadence used during March was lower during the entire test (74 rpm). The average cadence used during the hill climbing in March was 70 rpm for the 4 % gradient hill and only 55 rpm for the 8 % gradient hill despite the improvement in his WAnT power output.

Heart Rate. Graph 23 illustrates the heart rate (rpm) averaged per lap over the time period of the test.

Graph 23. Heart rate (bpm) during 1-hour distance trial for CS1 (Second Macrocycle)



* HR_{max} of incremental exercise test = 181 bpm.

(Rationale for connecting the data points was presented in Chapter Three.)

- Average heart rate achieved in October was 159 bpm (88 % of HR_{max}), and the highest was 171 bpm.
- A very low heart rate (bpm) was registered during the January test, despite the fact that the distance covered in January was the greatest. The highest heart rate reached only 156 bpm, and the average heart rate was 145 bpm, 80 % of HR_{max} achieved in the incremental test. This was a lot lower than the average heart rate obtained during October when it was 159 bpm and 88 % of HR_{max} .
- The average heart rate during March was 150 bpm (83 % of HR_{max}) and the maximum 160 bpm.

Summary of 1-Hour Distance Trial. Looking only at the HR data, one might conclude that CS1 did not put in the same effort in the distance trial in January. However, when these data is combined with the improved performance, one can conclude that, when comparing the January testing to that of October, the lower HR despite higher work output was as a result of greater aerobic fitness.

7.5 km Time Trial

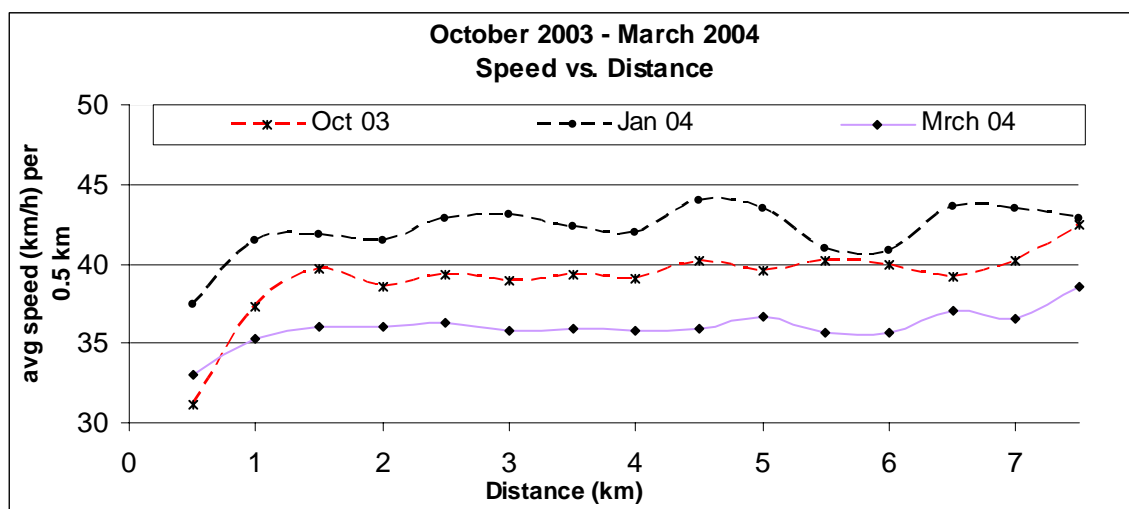
Results of the 7.5 km Time Trial for CS1 during the Second Macrocycle is presented in Table 21.

Table 21. Results of the 7.5 km time trial for CS1 (Second Macrocycle)

	October 2003	January 2004	March 2004
Time (min:s)	11:38	10:45	12:39
Avg cadence (rpm)	98±6	97±5	95±5
Avg speed (km/h)	39±2	42±2	36±1
Avg heart rate (bpm)	159±5	169±4.	160±3
Highest heart rate (bpm)	168	179	172

Time / Distance. Graph 24 illustrates the speed (km/h) averaged per 0.5 km achieved during the 7.5 km.

Graph 24. Average speed (km/h) during 7.5 km time trial for CS1 (Second Macrocycle)



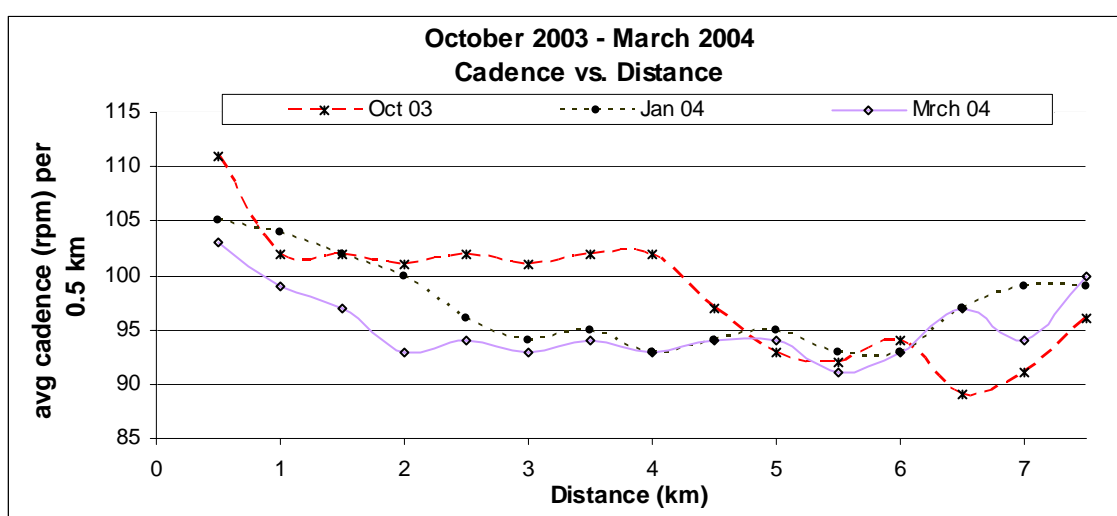
For the reason for connecting data points, see methodology.

- Graph 24 illustrates that the best speed was achieved during the January test. The tactics used by CS1 were to go out as fast as possible and maintain speed. A slight drop in speed was experienced between kilometers 5 and 6, but the pace was picked-up at the end.

- The average speed in March was the lowest (just above 35 km/h) and it was maintained throughout with a slight increase over the last 0.5 km. This indicates that the training between October to January improved CS1's speed endurance although a drop in sustained speed was experienced in March.

Cadence. Graph 25 illustrates the cadence (rpm) averaged per 0.5 km during the 7.5 km Time Trial.

Graph 25. Cadence (rpm) selection during 7.5 km time trial for CS1 (Second Macrocycle)

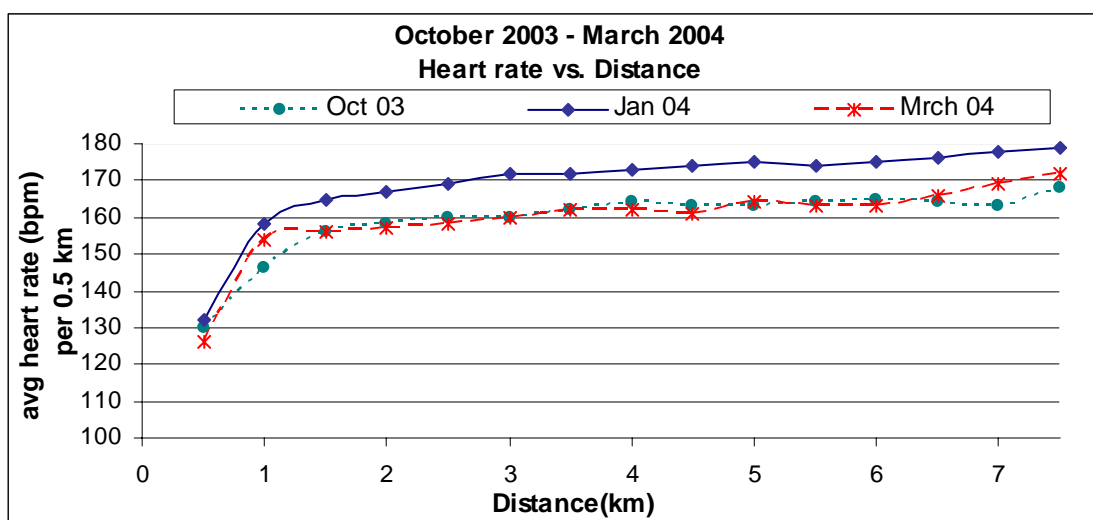


(Rationale for connecting the data points was presented in Chapter Three.)

- Average cadence declined from for October to January to March. (98 rpm to 97 rpm to 95 rpm).
- Graph 25 illustrates that there was a fast start in both January and March, with a decrease in cadence in the middle kilometers and a small increase in cadence over the last 1.5 km. The cadence was different in October, when he started fast, maintained a cadence of above 100 for 4 km and then showed a decrease in cadence below 95, with only a slight recovery towards the end. However, cadence cannot be interpreted alone (see summary on the next page).

Heart Rate. Graph 26 illustrates the heart rate (bpm) averaged per 0.5 km during the 7.5 km Time Trial.

Graph 26. Heart rate (bpm) during 7.5 km time trial for CS1 (Second Macrocycle)



HR_{max} achieved in incremental exercise test = 181 bpm.

(Rationale for connecting the data points was presented in Chapter Three.)

- Average heart rate in October was 88 % of HR_{max} and the highest was 168 bpm.
- In contrast, the average heart rate of 169 bpm (93 % of HR_{max}) achieved during January was 9 bpm higher than during March and 10 bpm higher than in October. The January results showed a steep increase in heart rate over the first kilometer with the heart rate of close to 170 bpm, compared to the second kilometer, and then a continuous increase as the heart rate climbed towards the 179 bpm at the end of the test. In January, CS1 was able to cycle at 93 % of HR_{max} (181bpm), and over the last 1km he averaged 98 % of HR_{max} . On average he cycled at a 5 % higher HR intensity than in March.
- The effort of March was nearly the same as in October, 2003, with an average heart rate of 160 bpm (88 % of HR_{max}) and a maximum heart rate of 172 bpm.

Summary of 7.5 km Time Trial. The intensity at which CS1 rode the 7.5 km time trial in January was on average 10 bpm faster than during the tests in October and March. This increased intensity was not due to the higher cadence, because the average cadence for January was the same as March. The time achieved in January was the second fastest time that he achieved on the 7.5 km time trial during the study. He showed more muscle endurance and an ability to sustain 93 % of his maximum heart rate over the duration of the 7.5 km time trial during the January testing.

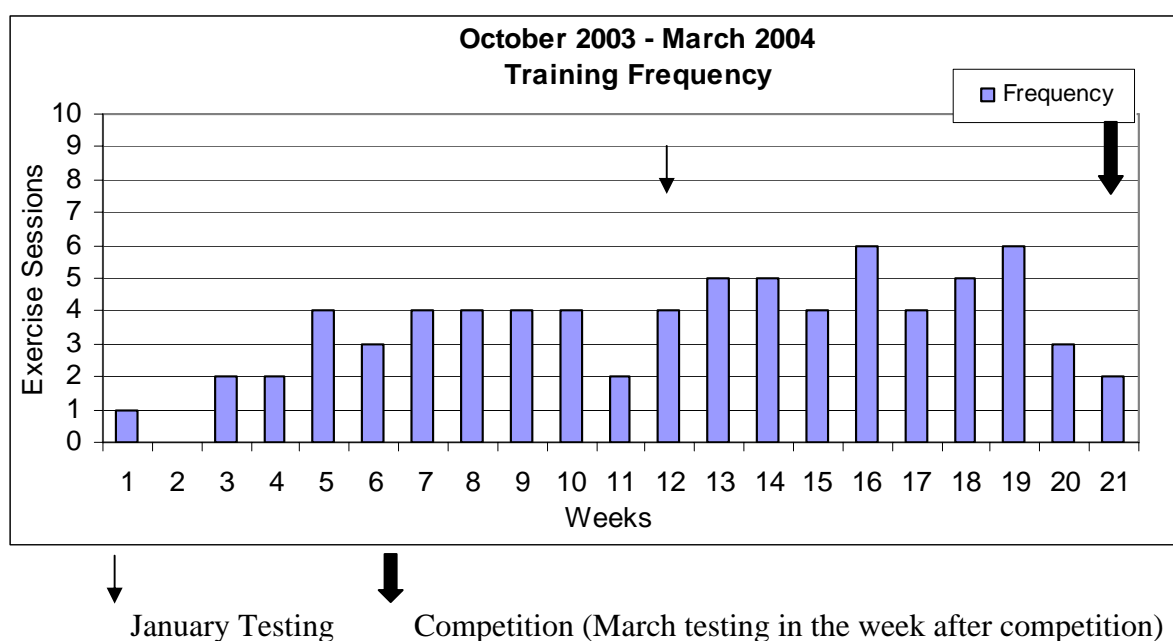
Training

Both heart rate monitor data as well as the training logs filled in by CS1 were used to determine the training intensity, volume, frequency as well as the mode of training during this macro-cycle.

Training Frequency

Graph 27 illustrates the average exercise sessions per week for this cycle.

Graph 27. Training frequency for CS1 (Second Macrocycle)

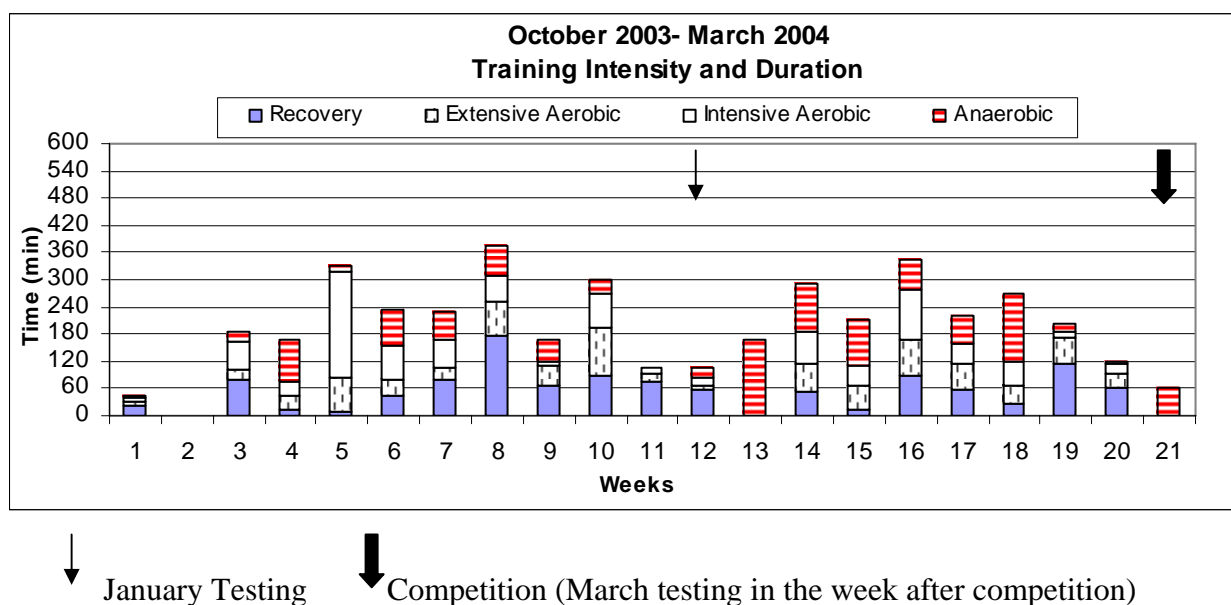


An average training frequency of three to four training sessions per week was documented for the first 12 weeks. After that, training increased to an average of five to six training sessions a week, with a drop in training sessions during the last week before competition and during the competition week. The steep drop in training during the last week before competition could be due to logistics, for example, lack of management support for training just prior to competition, difficulties with traveling arrangements, etc.

Training Intensity

Graph 28 is an illustration of the average time spent at different heart rate training intensities during each week.

Graph 28. Training intensities for CS1 (Second Macrocycle)



It is important to note that not all the training data were collected during Week 21. Data in this graph shows only heart rate data gathered on the Polar S720 watch. Weeks 1 and 2 of the training cycle indicate limited or no training due to the break from training after the previous competition. During the first six weeks of the macrocycle, training focus was on long sustained rides to build a base for future high intensity training. This can be seen by the limited amount of time spent in the anaerobic zone, which is where heart rate is higher than 85 % of maximal heart rate. No periodised training with systematic increase in training volume and intensity with subsequent recovery is noticed. During the last six weeks of the macrocycle, it was important to train more in the zone above 85 % of maximal heart rate, with enough recovery time to prevent overtraining. This was achieved to some extent by increasing the time spent in the anaerobic zone.

The maximum training time per week was achieved in Week 8, when slightly more than 360 minutes of training were reported. On average CS1 spend 3.4 hrs per week of training during the 20 weeks before competition. The macrocycle was planned in 3 x 6 weeks cycles with a three week tapering period, including competition week. For the first 6 weeks, CS1 trained on average 2.7 hours. The second 6 weeks he trained on average 3.6 hours. The third 6 weeks he trained on averaged 4.2 hours, and the last 2 weeks before competition an average of 2.7 hours per week were undertaken. This showed a 30 % increase in average volume from the first 6 weeks, to the second 6 weeks, 17 % increase from the second 6 weeks to the third, and a 36 % drop in training volume from the last six weeks to the tapering period,

two weeks before competition. Table 22 presents the percentage of training time spent in each training zone.

Table 22. Percentage of training time in each training zone (competition week excluded) for CS1 (Second Macrocycle)

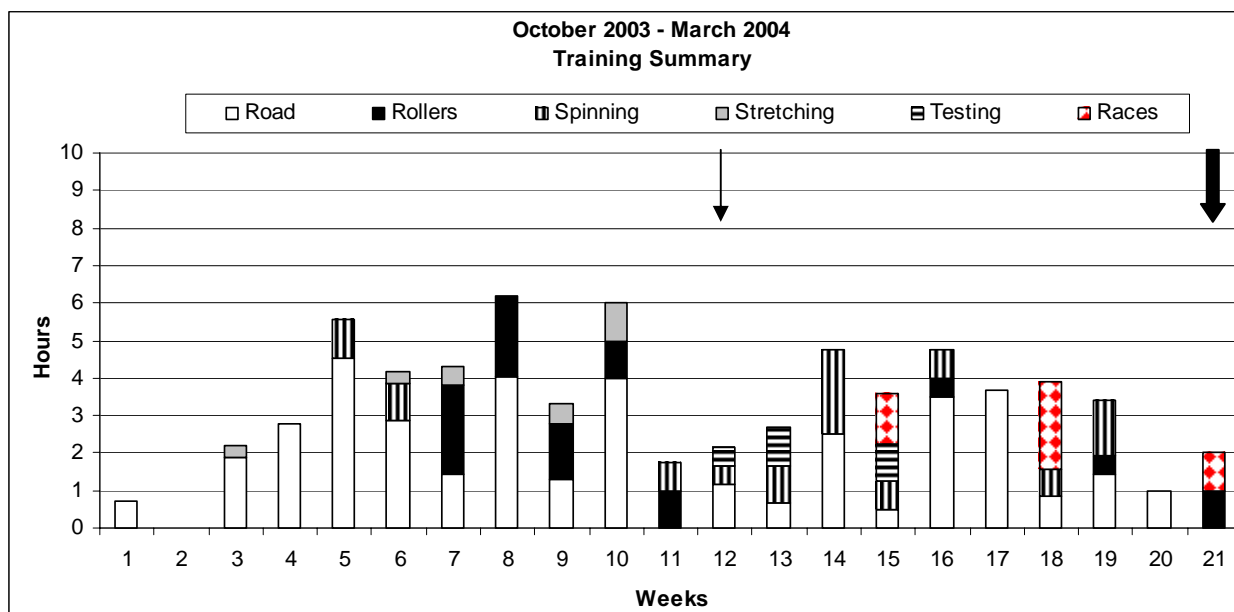
Weeks	Recovery Zone (<70%)	Extensive Endurance (70-80%)	Intensive Endurance (80-85%)	Anaerobic (>85%)
1- 6	17.4% (167 min)	18.1% (174 min)	43.0% (412 min)	21.5% (206 min)
7-12	42.8% (548 min)	21.2% (272 min)	18.3% (234 min)	17.7% (227 min)
13-18	16.0% (242 min)	19.0% (285 min)	21.6 % (324 min)	43.4% (652 min)
19-20	54.0 % (175 min)	30.0% (97 min)	10.5% (34 min)	7.5% (24 min)

The training period from weeks 1-12 was seen as base training time. However, in the first 6 weeks, 43 % of training time was spent in intensive endurance training and 21.5 % of time in the anaerobic zone: 64.5 % of the time (618 min) was spent above 80 % of HR_{max} . Thus relatively little time was spent in the target 80-70% zone. CS1 thus perceives an effort of 80-85 % HR_{max} as appropriate for base training and he did spend a lot of time in this zone. During the next 6 weeks, 64 % (820 min) of CS1's training time was spent below 80 % of training, but the majority of that was in the recovery zone. The testing in January was after 12 weeks of training and the last 6 weeks there of was not theoretically the kind of training intensity to support performance. Nonetheless training volume was high. During the next 6 weeks, the time spent above 80 % of HR_{max} increased to 65 %, with the majority above 85% of HR_{max} . This was a major shift in intensity.

Training Modes

Graph 29 illustrates the different training modalities used during this cycle.

Graph 29. Training summary for CS1 (Second Macrocycle)



↓ January Testing ↓ Competition (March testing in the week after competition)

During the first six weeks, 83 % of training time was spent on the road. This was beneficial because his roller trainer provides no resistance. The next 12 weeks 50 % of the training time was spent on the road, but roller training was substantial, probably explaining the HR data presented in the previous section. From weeks 12 to 18, spinning training formed part of his weekly training with a total of 23.5 % of total training time spent on the spinning bike. Spinning training is theoretically simulating interval training. Because the bicycle is fixed, the influence of his balance and coordination problems are minimized, which makes this a good training mode for CS1. During the first 10 weeks, stretching formed a regular part of his training, after which time no stretching was documented. Testing was the focus during weeks 12, 13 and 14. The races during the last six weeks were good for preparation for competition.

General Summary of Training

The greater amount of training time spent cycling on the road, as well as training at lower but sustained intensity, could have played a major role in the improvements found in

the 1-hour distance trial and the 7.5 km time trial during the January testing. However this did not translate into improved PPO or VO_2 max and there was even a decline in sprint power. Higher intensity training supported the improvements that were found during the maximal testing to fatigue in March, which revealed improved power output (anaerobic (WAnT) as well as aerobic capacity (incremental test to fatigue). The opposite results were found for the distance and the time trial where sustained endurance was needed. This indicates that some of the laboratory tests, namely the longer time trials are responsive to higher volumes of outdoor training, where as spinning and interval training on the road seemed to improve the shorter laboratory tests.

Direct Factors Targeted during the Second Macrocycle

The research question guiding this study focused on the management of selected direct factors important for sport performance management. The following rating scale reflects the investigator's perceptions of the degree of success in managing these factors.

Direct Factor	Score	Reasons
Performance Assessment	4	The cyclist achieved his goals for the competition in March to be selected for the Paralympic Squad. Laboratory assessments were completed with enthusiasm and motivation.
Periodised Planning of Training	4	The periodised plan was better implemented. This is noticed in the time spent in each training zone, frequency of training as well as the modes used.
Feedback on Training	3	The use of the heart rate monitor made monitoring easier and also more frequent feedback was possible. Training logs were still completed for more in depth information.
Training Sessions	3	The implementation of the training programme given to CS1 was also not entirely satisfactory. Difficulties in implementing the programme were factors like weather, early sunset, broken bicycle and lack of time due to working commitments. Implementation of gymnasium work was not possible due to transport problems.
Training Camp	4	The experience physiotherapist was concerned regarding the ergonomics in CS1's working environment.
Sports Medicine Services & Products	0	No services due to lack of financial support.

Score = Point out of 5, with 0 not achieved, 5 fully achieved.

Physiological Monitoring

Third Macrocycle: March, 2004 – October, 2004

The Third Macrocycle was set after the transition phase following the South African National Championships for the Physically Disabled held in April, 2004, until the Paralympic Games in Athens, 2004.

Goals for the Third Macrocycle

The goals for the Third Macrocycle were to achieve personal best performances at the Paralympic Games, including a medal. This was not an overestimation of his abilities if one takes his international performances over the previous two years into consideration.

Direct Factors Targeted during the Third Macrocycle

The following direct factors were identified for the Third Macrocycle:

1. Performance Assessment: The only competition evaluation would be at the Paralympic Games in Athens, September, 2004. Continuous performance assessment in the laboratory was done in June, July and after the Paralympic Games.
2. Periodised Planning of Training: Periodised plan was given to CS1 based on his training during the Second Macrocycle, and performance assessments during March, 2004.
3. Feedback on Training: Training logs continued to be used to interpret training, but the main source of training feedback was heart rate data, received on a weekly basis and analyzed with commercially available software (Polar Precision Performance Software).
4. Training Sessions: The training modes available to CS1 were road cycling, spinning, and roller trainers with no resistance. The priority was to spend as much time as possible on the road.
5. Training Camps: A two week training camp at Stellenbosch University.
6. Sports Medicine Services and Products: Funding was available for needs.

Physiological Evaluations

The first assessment was completed in June, 2004, just after the base training phase. The second assessment was six weeks later in July, after the two-week Paralympic Team training camp. After most of the tests in July, CS1 reported that he could feel the fatigue in his legs. The third assessment was conducted in October, within two weeks following the Paralympic Games. After the Paralympic Games, CS1 had bronchitis and was in bed for a week, with a one week rest before the testing was conducted. This definitely influenced his results in October, 2004. The goal for this macrocycle was to improve his power to increase his time trial ability, but it will also influence is road race.

Anthropometry

The results of the Anthropometry measurements are presented in Table 23.

Table 23. Anthropometric measurements of CS1 (Third Macrocycle)

Date	March 2004	June 2004	July 2004	October 2004
Age	23	23	23	23
Body mass (kg)	66	65	66.1	64.6
Height (cm)	172	172.2	172.1	172
% Fat	11	9.9	10.4	9.7
Somatotype	2.4 – 5 – 2.6	2.3 - 5.3 – 2.8	2.4 – 5.2 – 2.4	2.2 – 5.6 – 2.8

Body mass Variance in body mass from 65 kg in June to 66.1 kg in July to 64.6 kg in October is noted.

Height CS1's height varied with 1- 2 mm.

Fat percentage His fat percentage changed minimally – the difference between the highest and lowest values was only 1.3 %.

Somatotype The endomorphy and ectomorphy components stayed nearly constant throughout this phase.

General CS1's fat percentage and body mass were lower in October than they had been throughout this study, with the highest mesomorphic rating as well.

Incremental Exercise Test to Exhaustion

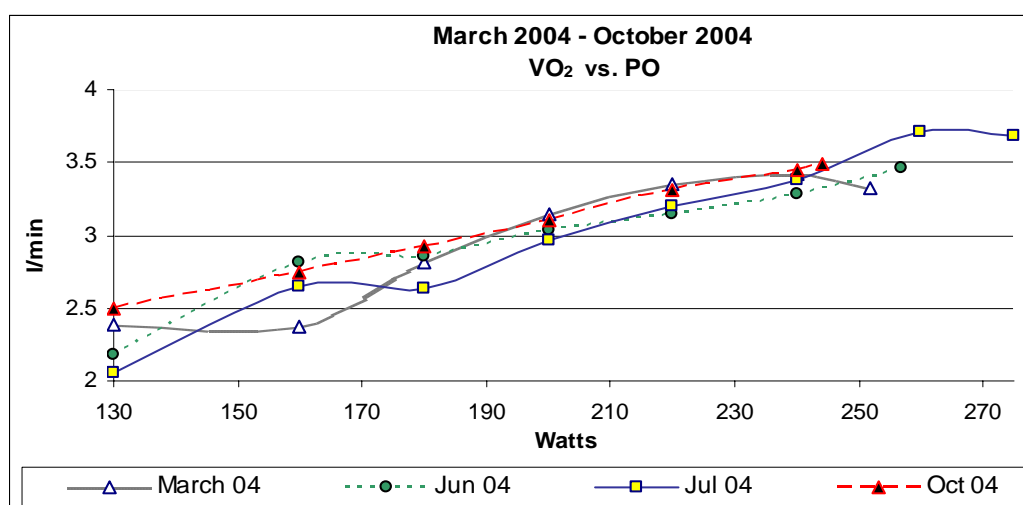
The results of this test are presented in Table 24.

Table 24. Results of the incremental exercise test to exhaustion for CS1 (Third Macrocycle)

	March 2004	June 2004	July 2004	October 2004
Total time of test (min:s)	16:35	17:02	19:01	15:27
VO ₂ max (l/min)	3.42	3.46	3.71	3.49
VO ₂ max (ml/kg/min)	51.9	53.3	56	54.1
HR _{max} (bpm)	181	179	181	181
Peak power (PPO)(Watts)	252	257	275	244
Peak power: body mass (W/kg)	3.82	3.95	4.16	3.78
Max lactate (mmol/l)	14.2	12.7	12.2	10.9
La ₂ (Watts)	120	115	114	Start
La ₂ (HR)	137	128	128	Start
La ₄ (Watts)	185	162	192	173
La ₄ (HR)	160	148	150	157
Max RER	1.09	1.07	1.02	1.04
RER of 1 (Watts)	220	160	240	200
RER of 1 (HR)	169	147	169	165
Time cycled above RER 1	4:00	12:02	4:01	5:30

Graph 30 is an illustration of the efficiency of pedaling expressed as the relationship between oxygen used and work done (watts of pedaling).

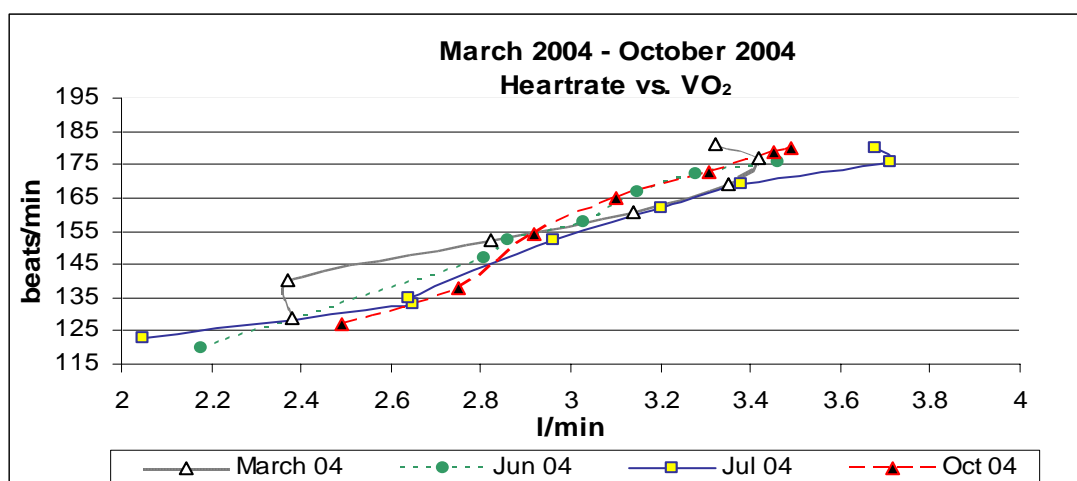
Graph 30. Pedaling efficiency for CS1 (Third Macrocycle)



- The best PPO and VO_2max results were achieved during the July testing, with lower VO_2 thus more efficient work up to 180 W of power output. This indicates improved pedaling efficiency and less wasteful movement. The peak aerobic power in watts and watts/kg increased with 7 % and 5 % respectively from June to July, over a period of 6 weeks.
- The October results were discouraging, but the fact that CS1 was sick after the Paralympic Games definitely affected his performance.

Graph 31 illustrates the relationship between heart rate and oxygen uptake (VO_2).

Graph 31. Heart rate for CS1 (Third Macrocycle)

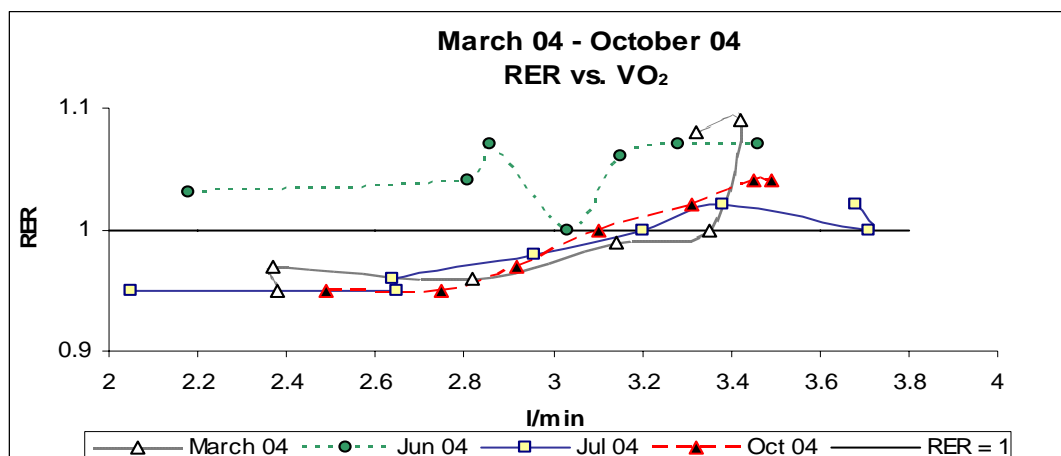


- HR_{max} achieved in March was 181 bpm.
- The maximal heart rate obtained during the June test was 179 bpm. The efficiency with which the heart could deliver oxygen during June improved since March, especially at lower VO_2 values below 3 l/min.
- HR_{max} achieved in July was 181 bpm, and the most efficient heart rate was in July, compared to June or October at higher intensities (right shift). CS1's ability to cycle at lower heart rate indicates a greater stroke volume or possibly an increase in his arterial-mixed venous oxygen difference. The decrease in heart rate at the higher levels of VO_2 is indicative of the heart's improved ability to provide oxygen. This was the main goal for the training period before July and it was achieved.

- HR_{max} in October was 181 bpm, with the heart rate graph at lower levels nearly the same as in July. However, at higher VO_2 intensities, it was less efficient.

Graph 32 illustrates the respiratory exchange rate (RER) relative to the oxygen uptake.

Graph 32. Respiratory exchange rate for CS1 (Third Macrocycle)



The longer a cyclist can ride under an RER of 1, the better his/her capacity to use oxygen to burn fat to produce energy for the cycling action. The testing in June indicated an RER that started above 1.0 and continued above 1.0 for the duration of the test, with little increase above the starting value.

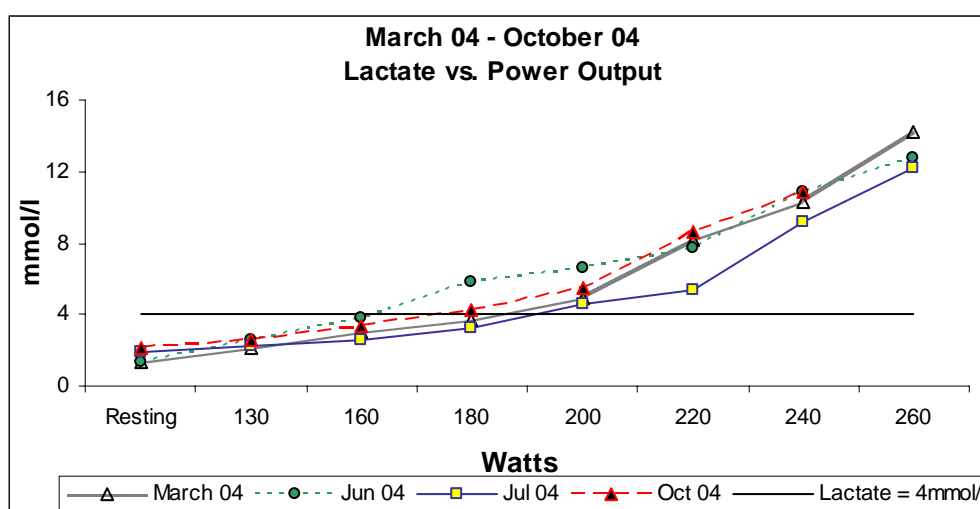
- RER of 1 was achieved at 220 Watts and a heart rate of 169 bpm in March. Maximum RER achieved was 1.09.
- CS1 came for testing after a busy and stressful day at work in June. AN RER of 1 was achieved at 160 Watts and a heart rate of 147 bpm. Maximum RER achieved was 1.07.
- In July a RER of 1 was achieved at 240 Watts and a heart rate of 169 bpm. A maximum RER of 1.02 was achieved.
- In October a RER of 1 was achieved at 200 Watts and a heart rate of 165 bpm. A maximum RER of 1.04 was achieved.

Maximal values of higher than 1.1 were not achieved on these tests. This is an indication that CS1's training programme was well designed to increase his ability to use

oxidative processes to provide energy at a much higher intensity. The low maximum RER values can also show that his ability to really work anaerobically can improve. The tired legs in July might have resulted in the inability to sustain anaerobic work in the last workload. Alternatively CS1 may have learned not to hyperventilate.

Graph 33 is an illustration of blood lactate concentrations (mmol/l) at each workload (Watts) during the incremental test.

Graph 33. Lactate accumulation for CS1 (Third Macrocycle)



- OBLA was achieved at 73 % of PPO (252 Watts) during March.
- OBLA was achieved at 63 % of PPO (257 Watts) in June.
- OBLA was achieved at 70 % of PPO (275 Watts) in July.
- OBLA was achieved at 71 % of PPO (244 Watts) in October.

The graph indicates that CS1 had adapted to prevent early lactate accumulation in his blood after the preparation phase in July. OBLA indicates a better capacity in July to cycle at higher intensities before an increase above 4 mmol/l in blood lactate levels. This should improve performance. Despite tired legs, the maximal lactate in July was still high (>10 mmol). This means that the lower RER was not due to the decreased ability to use anaerobic metabolism.

Wingate Test (sprint power and resistance to fatigue)

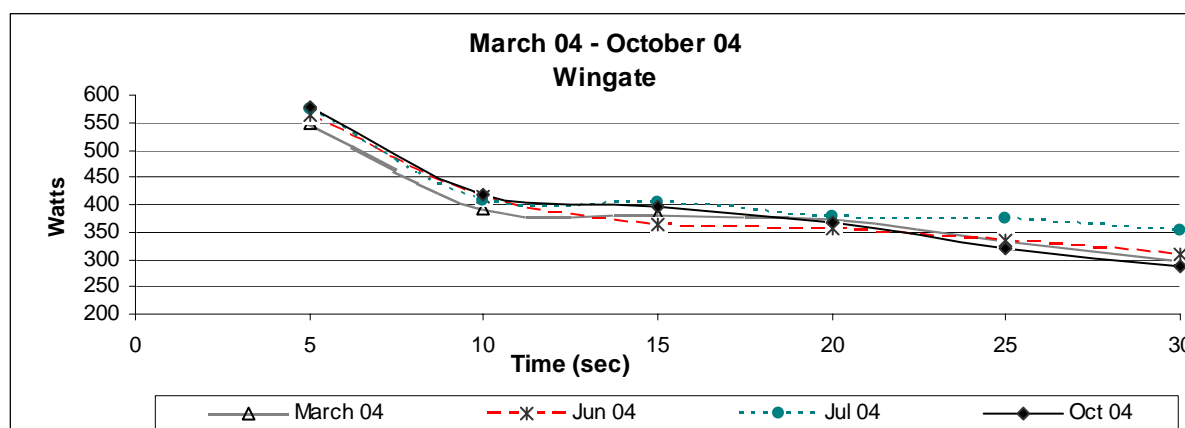
The results of the Wingate test are presented in Table 25.

Table 25. Values obtained from the 30 second Wingate test for CS1 (Third Macrocycle)

	March 2004	June 2004	July 2004	October 2004
Resistance	9.8 % / BW	9.8 % / BW	9.8 % BW	9.8 % BW
Body mass (kg)	66	65	66.1	64.6
Peak sprint power (Watts)	550	565	576	577
Relative peak sprint power (W/kg)	8.33	8.68	8.73	8.92
Avg sprint power (Watts)	389	389	415	395
Avg relative sprint power (W/kg)	5.89	5.99	6.29	6.11
Minimum sprint power (Watts)	298	308	353	288
Avg sprint power/ peak sprint power %	71 %	69 %	72 %	68.5 %
Fatigue index (W/s/kg)	0.127	0.131	0.113	0.149

Graph 34 is an illustration of the average power output (watts) during each 5 seconds of the 30 second Wingate test.

Graph 34. Sprint power and resistance to fatigue for CS1 (Third Macrocycle)



- During June, the peak sprint power increased to 564.5 Watts from the 550 Watts in March, and the mean sprint power stayed constant at 389.4 Watts.

- In July, the peak sprint power showed a further increase to 576 Watts, and the mean sprint power increased to 415 Watts. The capacity to sustain the sprint power (mean power output) was the best during July.
- The peak power output during the October Wingate test remained high but the mean sprint power decreased slightly to 394.5 Watts. The fact that CS1 had tapered before the competition at the end of September might have had an influence on the results in October. Additional detraining could have occurred because he also had been sick.

When the body mass is taken into account, CS1's relative peak power increased from June to October 2004 by 2.7 % and his relative mean power increased by 2 %. The best relative mean sprint power was achieved in June, with a 5 % increase in mean sprint power from June to July. This is indicative of his muscles' capacity to resist fatigue that is important for time trials, particularly with shorter distance and high intensity (7.5 km time trial).

1-Hour Distance Trial

The results of this test are presented in Table 26.

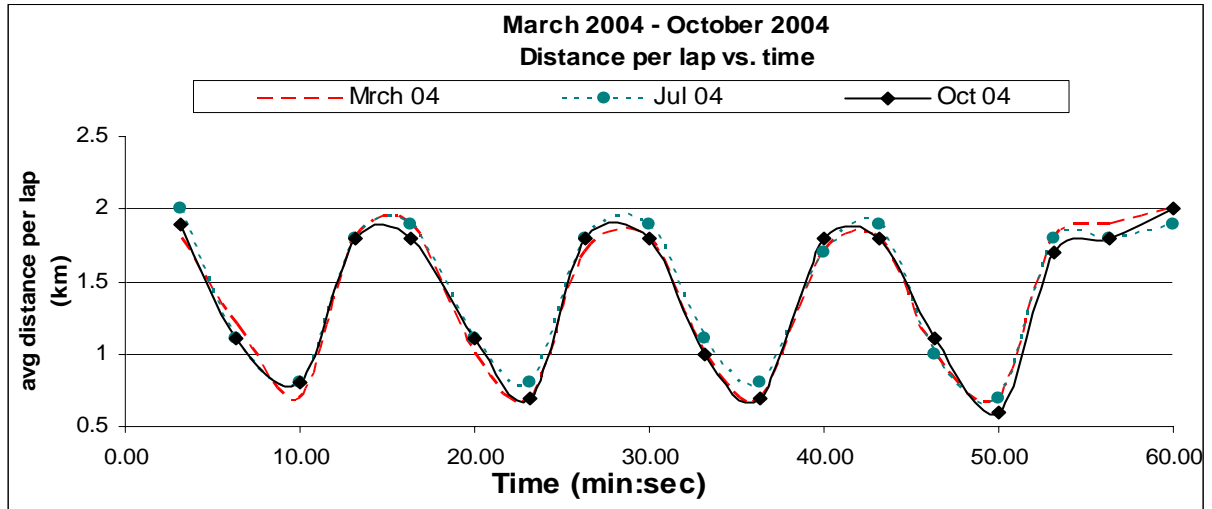
Table 26. Values obtained during the 1-hour distance trial for CS1 (Third Macrocycle)

	March 2004	June 2004	July 2004	October 2004
Total distance (km)	25.2	DID NOT DO THE TEST	25.8	25.2
Avg cadence (rpm)	74±14		83±14	80±16
Total distance 4 % incline (km)	4.2		4.3	4.4
Avg cadence 4 % incline (rpm)	70±6		75±5	70±4
Total distance 8 % incline (km)	2.8		3.1	2.8
Avg cadence 8 % incline (rpm)	55±2		62±2	56±3
Avg heart rate (bpm)	150±8		157±7	146±8
Highest heart rate (bpm)	160		168	160

Total Distance

Graph 35 illustrates the average split distances over time.

Graph 35. Lap distance (km) during 1-hour distance trial for CS1 (Third Macrocycle)

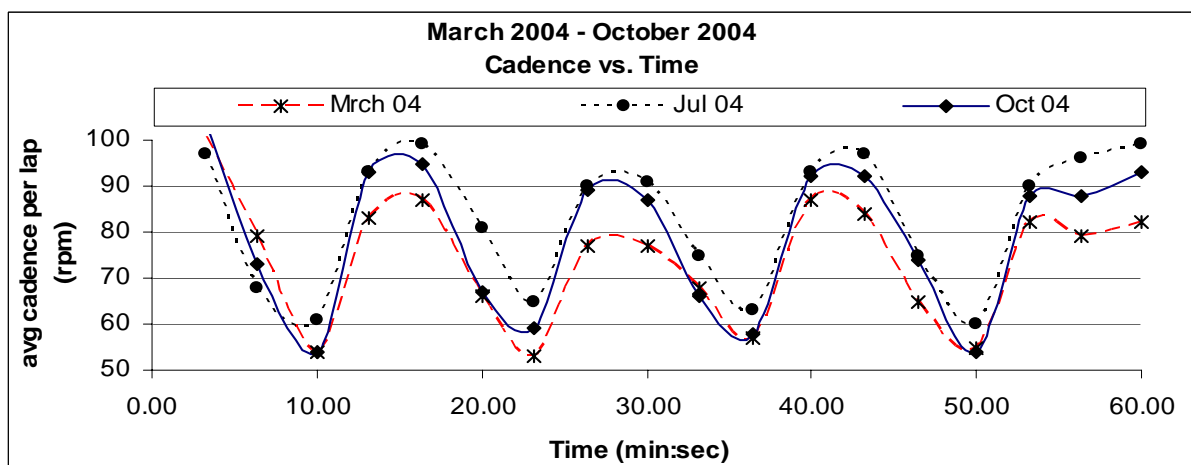


(Rationale for connecting the data points was presented in Chapter Three.)

No real differences are noticed in the distance covered during flats, 4 % gradients or 8 % gradients, among the different testing times. With the three testing distances between 25.3 km in March, 25.8 km in July and 25.2 km in October.

Cadence. Graph 36 is an illustration of the average cadence per lap over time.

Graph 36. Cadence (rpm) selection for 1-hour distance trial for CS1 (Third Macrocycle)



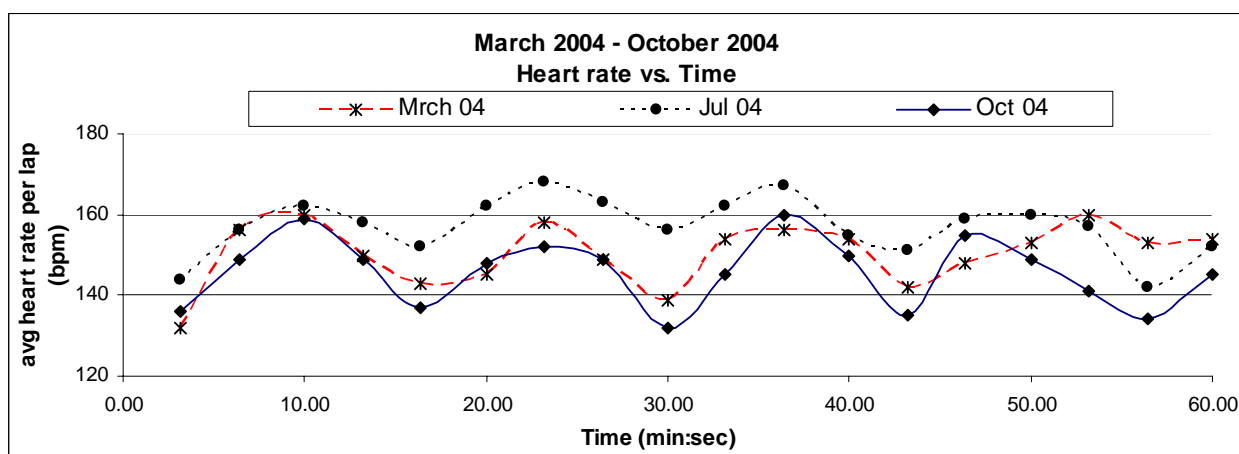
(Rationale for connecting the data points was presented in Chapter Three.)

- Average cadence in July increased from 74 rpm in March to 83 rpm, with improvement from 70 rpm to 75 rpm on the 4 % hill and from 55 rpm to 62 rpm on the 8 % hill.
- The cadences decreased in October to an average of 80 rpm, with the 4 % hill and the 8 % hill more similar to March.

A great variety in cycling cadence was documented. A higher cadence during July and October on the flat part of the trial is visible. These results did not translate into better performance, which suggests that cadence is a matter of preference rather than performance.

Heart Rate. Graph 37 illustrates the average heart rate (beats/minute) over time.

Graph 37. Heart rate (bpm) during 1-hour distance trial for CS1 (Third Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

- Average heart rate during March was 150 bpm (83 % of HR_{max}), with a highest of 160 bpm.
- During July the average heart rate changed to 157 bpm (87 % of HR_{max}), with a highest of 168 bpm.
- October shows a change in average heart rate to 146 bpm (80 % of HR_{max}), with a highest of 160 bpm.

Graph 37 indicates a higher heart rate (and therefore physiological intensity) during the July test, with only a 0.6 km improvement in performance. This meant that CS1 was cycling at a higher intensity during July than October. The training camp before and his

fatigue might also have resulted in a higher heart rate during July, than October when he was rested, although he was sick the week before.

Summary of the 1-Hour Distance Trial. The distances covered during the July and October testing was better than the First Macrocycle but not as good as in the Second Macrocycle.

7.5 km Time Trial

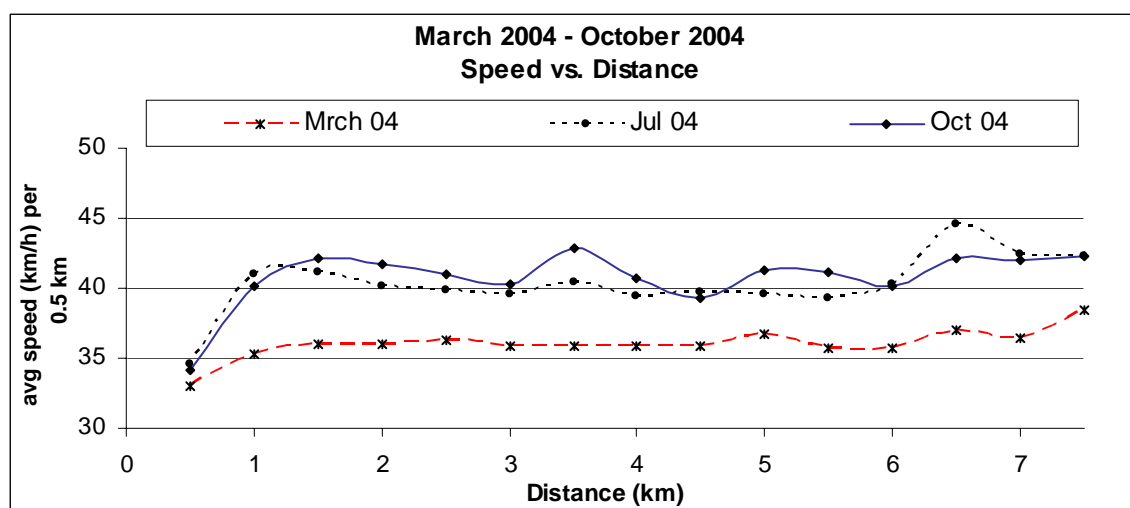
Results of the 7.5 km time trial are presented in Table 27.

Table 27. Results during the 7.5 km time trial for CS1 (Third Macrocycle)

	March 2004	June 2004	July 2004	October 2004
Time (min:s)	12:39	DID NOT DO THE TEST	11:23.7	11:19.6
Avg cadence (rpm)	95±5		102±3	101±5
Avg speed (km/h)	36 ±1		40±2	41±2
Avg heart rate (bpm)	160±3		165 ± 6	161±6
Highest heart rate (bpm)	172		178	171

Time / Distance. Graph 38 illustrates the speed (km/h) averaged per 0.5 km during the 7.5 km time trial during the Third Macrocycle.

Graph 38. Average speed (km/h) during 7.5 km for CS1 (Third Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

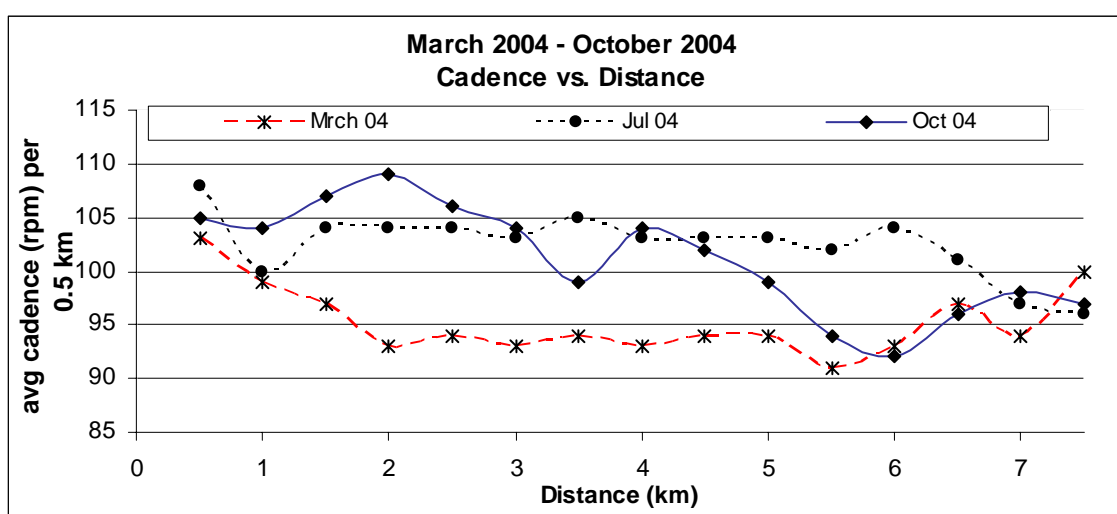
- The average speed during the March test was 36 km/h.

- During July, an average speed of 40.29 km/h was achieved. The July pacing started the same as in October and speed was maintained close to 40 km/h. An attempt to increase speed was made at the 6 km mark, but CS1 was not able to maintain the speed and a drop in speed was experienced at the 6.5 km mark and performance could not match that achieved in January of the same year.
- In October, there was more variation of speed during the test, but the average speed of 41 km/h was not very different from July.

The tactic used by CS1 in July and October was to go out as fast as possible, and maintain the speed. The results of the October test are inconsistent, showing increases and decreases in speed indicating inconsistent pacing. A 5.5 % improvement in average speed was made between March and October.

Cadence. Graph 39 illustrates the cadence (rpm) averaged per 0.5 km during the 7.5 km Time Trial.

Graph 39. Cadence (rpm) selection during 7.5 km time trial for CS1 (Third Macrocycle)



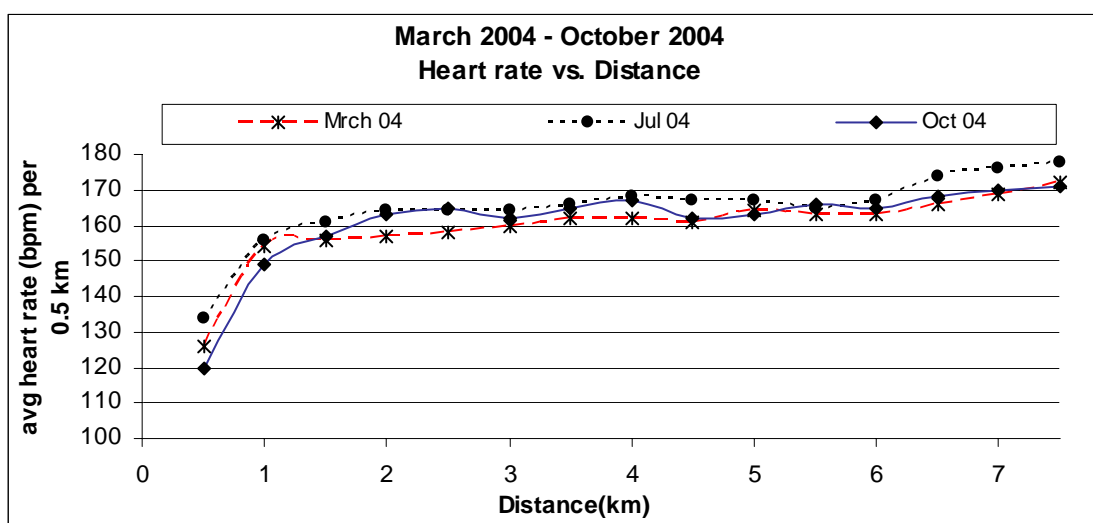
(Rationale for connecting the data points was presented in Chapter Three.)

- Average cadence achieved during March was 95 rpm.
- During July, average cadence increased to 102 rpm. In July, there was a fast start of above 100 rpm, and the cadence was maintained at close to 100 rpm until the 6 km mark, when the cadence lowered.

- The cadence of July was maintained during October. The graph of October's results shows a continued decrease in cadence from above 105 rpm at the 2 km mark to below 95 rpm at the 6 km mark, after which it picked up to slightly above the 95 rpm mark, indicating less consistency than in July, despite the same average cadence.

Heart Rate. Graph 40 illustrates the heart rate (bpm) averaged per 0.5 km during the 7.5 km Time Trial

Graph 40. Heart rate (bpm) during 7.5 km time trial for CS1 (Third Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

- During July, the average heart rate improved from 160 bpm in March of 165 bpm (91 % of HR_{max}) and a highest of 178 bpm was achieved.
- During October, the average heart rate changed slightly to 161 bpm (89 % of HR_{max}) with a highest of 171 bpm.

Although the heart rate during July was higher, the time was slower. This is indicative that CS1 was better prepared for the 7.5 km Time Trial in October. It needs to be taken into account that the October test was completed 3 weeks after competition and the cyclist had been sick. It is possible that recovery could have played a role in the result.

Summary of 7.5 km Time Trial. CS1's intensity in the 7.5 km time trial in July and October was less than 90 % of his maximal heart rate. The July test showed good constant cadence and speed. The inability to resist fatigue resulted in the decrease in speed and

cadence towards the end of the trial. The October test showed a variance in terms of speed and cadence.

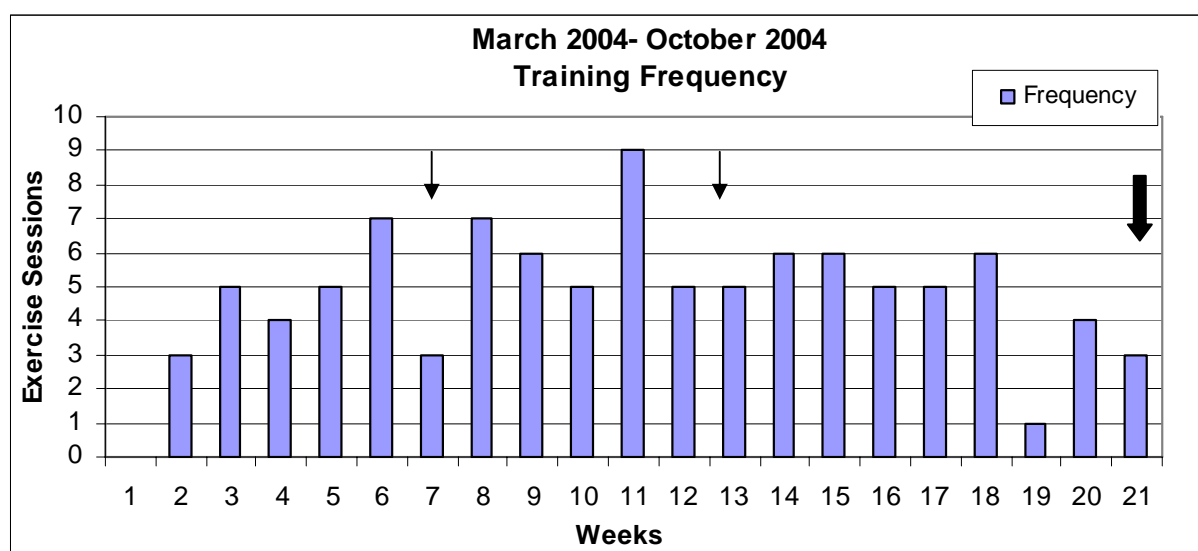
Training

Heart rate monitor data as well as the CS1's training logs were used to determine the training intensity, volume and frequency as well as the mode of training during this macro-cycle.

Training Frequency

Graph 41 illustrates the exercise sessions per week for the Third Macrocycle.

Graph 41. Training frequency for CS1 (Third Macrocycle)



↓ Testing (Weeks 6, 12, 13, 14 and after week 21) ↓ Main Competition – Paralympic Games

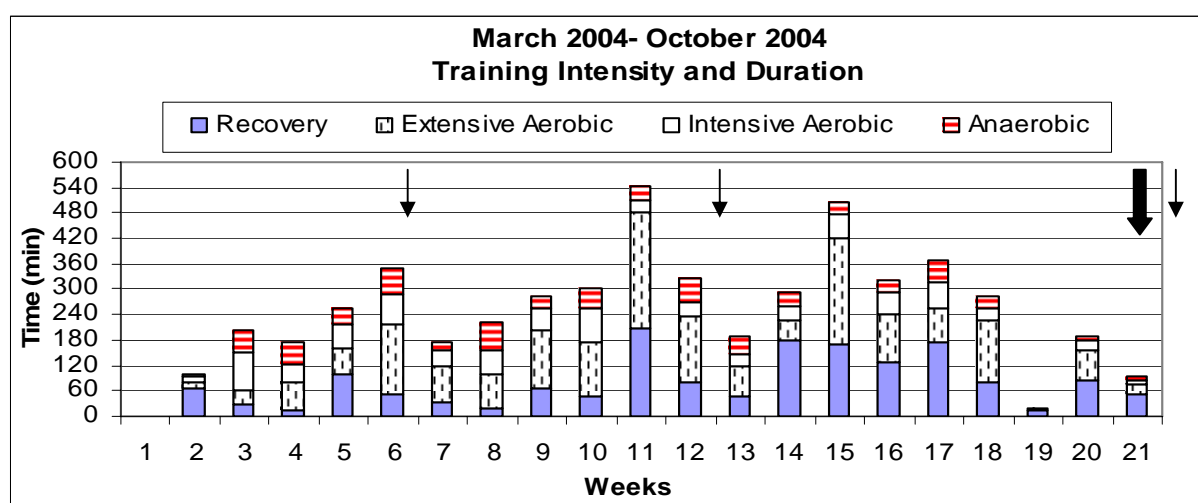
The average number of training sessions during the first 6 weeks was 4 sessions per week, with a range between 0 -7 sessions per week. The next 6 weeks, 5.8 sessions per week were conducted, with a range between 3 – 9 sessions per week. Weeks 11 and 12 were during the Paralympic training camp and the increase in sessions in Week 11 was possible due to freedom from work commitments. During weeks 13-18, the training frequency was 5.5 sessions per week, which was constantly achieved without a lot of fluctuation (range 5 - 6 sessions per week). A slight drop in training frequency was noted towards competition time,

and that was planned for tapering purposes with 1 session in the first tapering week, 4 sessions in the second tapering week, and 3 sessions in the first week of competition. Week 19 (the first tapering week), was also the same week as the holding camp in Johannesburg. Week 20 was the first week in Athens at the Paralympic Village.

Training Intensity

Graph 42 is an illustration of the time spent at different training intensities in each heart rate zone during each week

Graph 42. Training intensity for CS1 (Third Macrocycle)



↓ Testing (Weeks 6, 12, 13, 14 and after week 21) ↓ Main Competition – Paralympic Games

Graph 42 illustrates that the Third Macrocycle reflected the best periodised training plan of the three macrocycles. Gradual increases in volume each week are visible, with recovery weeks interspersed. Time spent regularly in the zones lower than 85 % of maximum, is also visible. Weeks 11 and 12 were the weeks spent at the Paralympic training camp, while Week 19 was spent at the holding camp for the Paralympic Games. Only limited training was possible during the holding camp due to sponsor commitments, difficulties in training area for the tricycle and other commitments. It is important to note that not all the training sessions during Weeks 20 and 21 were monitored due to the disruptions in training at the Paralympic Games.

During the first six weeks of the Third Macrocycle, training focus was on long, sustained rides to build a base for high intensity training. Relatively good periodised training

with systematic increase in training volume and intensity with subsequent recovery is noticed. The maximum training time per week was achieved in Week 11 (training camp), when 9 hrs of training was reported. On average, CS1 spent 4.3 hrs of training per week during the 20 weeks before the competition week. The macrocycle was planned in 3 x 6 weeks cycles with a three week tapering period, including competition week. For the first 6 weeks, CS1 trained on average 3 hrs, the following 6 weeks 5.2 hrs (training camp), the following 6 weeks, 5.4 hrs of training, and the last 2 weeks before competition he trained an average of 1.75 hrs. Note that all training data during the last two weeks was documented. This shows a 41.5 % increase in average volume from the first 6 weeks to the second 6 weeks, a 5.5 % increase from the second 6 weeks to the third and a 89 % drop in training volume from the last six weeks to the tapering period (two weeks before competition).

Table 28: Percentage of training time in each training zone for CS1 (Third Macrocycle - competition week excluded)

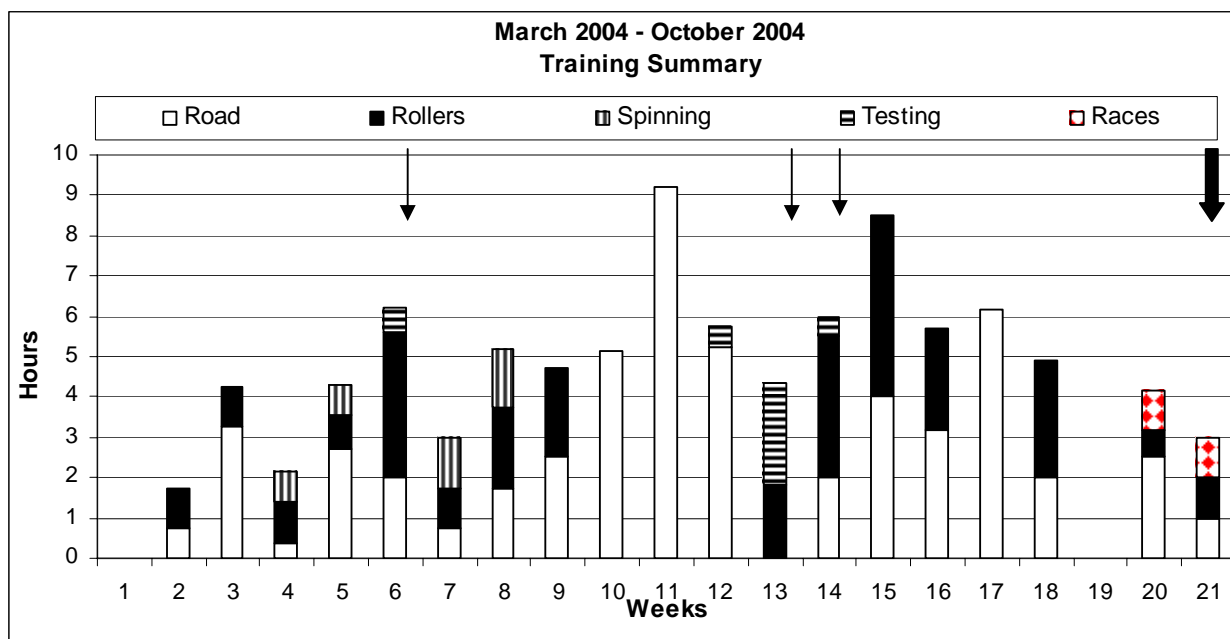
Weeks	Recovery Zone (<70%)	Extensive Endurance (70-80%)	Intensive Endurance (80-85%)	Anaerobic (>85%)
1- 6	24% (259 min)	31% (336 min)	26% (283 min)	19% (205 min)
7-12	24.5% (455 min)	46.2% (858 min)	15.5% (288 min)	13.8%(256 min)
13-18	39.7% (778 min)	36.3% (712 min)	12.7% (248 min)	11.3% (222 min)
19-20	47.1% (99 min)	35.7% (75 min)	11.4% (24 min)	5.7% (12 min)

For the first 6 weeks, 55 % of training time was spent below 80 % of HR_{max} and 19 % of time in the anaerobic zone (>85 % of HR_{max}). The June testing was completed after the first 6 weeks of training. During the next 6 weeks, 70.7 % of CS1's training time was spent below 80 % of training. The testing in July was after 12 weeks of training and the two weeks of training camp (Weeks 11 & 12). It can be seen that more training time is spent in the heart rate zones below 80 % of HR_{max} .

Training Modes

Graph 43 illustrates the different training modalities used during the Third Macrocycle.

Graph 43. Training summary for CS1 (Third Macrocycle)



↓ Testing times ↓ Competition times (last testing conducted two weeks after competition).

It was difficult for CS1 to do road training after work during the winter months. This is why roller training and some spinning formed a larger part of training than was ideal. During weeks 1 – 6, 40 % of training time was spent on the rollers. Weeks 10, 11 and 12 shows a great deal of road training (75 % of training at the camp was on the road). Testing occurred in Weeks 6, 12, 13 and 14. Weeks 11 and 12 were the two weeks at the training camp when CS1 could train during the day, with a coach as well as other team members. No work commitments influenced the training schedule. During weeks 13 – 18, 43 % of training time is conducted on the rollers. One area that was a problem was the lack of race training before the competition time.

General Summary of Training

If all factors are taken into consideration the periodised training summary for the Third Macrocycle was better organized and conducted. The greater percentage of training was

under 80 % of HR_{max} , with a slow increase in training intensity. It is a fact that roller training will play a great part in his training, due to personal circumstances. Roller training needs to be more functional. The main goal was to improve leg power and the incremental test to exhaustion and Wingate test results support the fact that it was achieved.

Direct Factors Targeted during Third Macrocycle

The research question guiding this study focused on the management of selected direct factors important for sport performance management. The following rating scale reflects the investigator's perceptions of the degree of success in managing these factors.

Direct Factor	Score	Reasons
Performance Assessment	4	CS1 achieved his goal, by winning the bronze medal in the road time trial at the Paralympic Games. His road race was cut short by a cycling accident. Laboratory assessments were completed with enthusiasm and motivation. Two factors that could have influenced the results, were the amount of training conducted at the training camp and CS1 had not recovered before testing was conducted. The October test results were influenced by the fact that CS1 was sick after the Paralympic Games and had a two-week lay-off between competition and assessment.
Periodised Planning of Training	4.5	The periodised plan was implemented as closely as possible. This is noticed in the time spent in each training zone, frequency of training as well as the modes used. The only area of concern was the lack of competition training as well as the training at the holding camp and Games, which was not fully documented.
Feedback on Training	4	The use of the heart rate monitor made monitoring easier and also more frequent feedback was possible. Training logs were still completed for more in-depth information. At competition times, CS1 did not want to complete the training logs or use heart rate monitor.
Training Sessions	4	Difficulties in implementing the programme were factors like weather, early sunset, broken bicycle and lack of time due to working commitments. The training sessions at the training camp were excellent and notice should be taken of the amount and quality of training that was possible with training partners and when work commitments were removed.
Training Camp	4	Positive feedback from CS1 and the results are noticeable in the physiological assessments. Video footage of CS1 was taken. Coaching was conducted and a lot of time was spent on competing in the road time trial which had been a problem for CS1.
Sports Medicine Services & Products	4	Full service available. Full medical, nutritional, psychological and vision assessment completed at first training camp in May, 2005 by the team professionals. Feedback was given to CS1 by them. Due to confidentiality, no feedback was given to the investigator. During the training camp in July, two massage sessions per week were given to CS1, as well as two aqua-recovery sessions. CS1 received a new frame (lighter and more aerodynamic) during this macrocycle. But this would not affect laboratory testing.

Score = Point out of 5, with 0 not achieved, 5 fully achieved.

Summary of the Management of Selected Direct Factors Targeted for CS1

The research question guiding this study focused on the management of selected direct factors important for sport performance management. The following is a discussion of the selected direct factors, the outcomes as well as the circumstance that could have influenced the outcomes.

Performance Assessments

Competitions

CS1 was able to compete in all the major competitions available for him. The results were a true indication that he performed well at these competitions (medals at all the events). The only drawback was the accident in the road race at the Paralympic Games. Race performance results are the best measure of athletic success. However, unlike some other cycling events (e.g. Cape Argus, Tour de France, etc), the road races for cyclists with disabilities are not consistently held over the same distances, let alone similar courses and conditions. In particular, with cerebral palsy cyclists who find hill-climbing difficult due to their lack of power on the affected side and difficulty in coordination, times differ substantially for a cyclist from race to race. Therefore, this section will focus only on performances in the controlled environment of the laboratory.

Physiological Monitoring

Anthropometry. The data indicated that CS1 had an average fat percentage of 10.6 % during Paralympic competition, with the range 9.7 - 11% over the three macrocycles. According to Winnick & Short, (1995) his cerebral palsy should not have influenced his skinfold measurements. CS1's average body mass at competition time was 65.4 kg with a range of 64.6-66 kg. The lowest value was at the Paralympic Games following the Macrocycle Three. The range of body mass during off-season varied between 65.2 - 66.4 kg, so it can be concluded that CS1's body mass did not vary much. His average BMI (body mass index) at competition time was 22.1 kg/m². Comparing this to the anthropometric characteristics of an able-bodied cyclist, his average fat percentage was slightly above the range of 8 -10 %, and his BMI was equal to that of a time trial specialist (Lucia et al., 2001), but higher than that expected from a climber (19-20 kg/m²).

Incremental Exercise Test to Exhaustion: Pedaling efficiency. Oxygen uptake at a given sub-maximal workload for children with cerebral palsy has been found to be equal to their able-bodied peers (Rose et al., 1993), but oxygen cost has been found to be higher for persons with cerebral palsy (Bowen et al., 1999; Unnithan et al., 1996). The efficiency of persons with cerebral palsy is therefore less.

At the first test during March, 2003, CS1 had a maximum PPO of 233 Watts and a VO_2 max of 3.49 l/min. The peak values achieved in PPO and VO_2 max were during the July, 2004 testing, with values of 275 Watts and 3.71 l/min respectively. The values of October, 2004 were lower than July, 2004. A reason for this could be that CS1 was sick between competition time and testing time. An 18 % increase in Watts from start to maximum value (July) is documented for CS1. The VO_2 max shows a 6 % increase. Literature indicates PPO as an important contributor to performance (Coyle et al., 1991). Greater improvements in PPO than in VO_2 max can be explained by the fact that PPO increases linearly over time but VO_2 max can plateau at the end of a test.

In a summary by Mujika & Padilla (2002), cyclists were classified according to training and racing status. CS1 falls into the well-trained category, which means that values for PPO/kg between 5.0 - 6.0 W/kg and VO_2 max values between 5.0 - 5.3 l/min, are anticipated. CS1's maximum value for VO_2 max was 30 % lower (5.3 L/min) and the PPO/kg value was 31 % lower (6 W/kg) than the well-trained cyclists.

The investigator calculated correlation coefficients (Pearson product moment correlation) between the different laboratory tests and the total as well as percentage of training time spent in each zone. No statistically significant correlations had been found due to small number of data points (4).

The incremental tests to exhaustion from October, 2003 – October, 2004 (6 tests), were conducted on the LODE ergometer, which was able to determine the power output of the left and right leg separately as well as the range of power output across each revolution of the pedal.

Table 29. Summary of the pedal force measurements during incremental tests to exhaustion for CS1

	130 W	160 W	180 W	200 W	220 W	240 W	260 W	280 W
Avg RPM	97.2±3.4	97.5±5.6	95.8±9.5	91.8±4.9	88.67±4.3	89.7±7	91.5±3.54	74
Avg Watts Left	49.8±3.1	62.5±4.23	71.8±4.8	77.3±3.8	92.7±8.1	99.8±3.7	110±2.8	123
Avg Watts Right	91.2±4.1	108±5.3	118.7±7.2	129.2±6.6	141.3±5.2	148.2±8	160±11.3	173
Avg Max Watts Left	315.3±8.7	360±15.97	396.2±25.7	399.8±24.9	446.5±25.4	464.7±18.3	497±1.4	504
Avg Max Watts Right	411.8±16.9	470.8±14.4	501.7±11	521.3±18.3	548.3±14.5	572±24.6	609±7.1	605
Avg Min Watts Left	-209±17	-211.5±25	-193.5±33	-176.3±18	-159.7±15	-165.8±23	-167.5±4	-113
Avg Min Watts Right	-126.7±16	-126.7±28	-118±36	-95.3±13	-88.7±17	-95±16	-90±24	-61
Efficiency	65.2±0.8	68.8±2.5	73±4.2	77±1.7	81.3±1.6	82.2±2.8	82	90
Ratio L	35.8±2.2	36.5±2.2	37.5±2.2	37.5±1.1	39.5±2	40.33±1.4	41±2.83	42
Ratio R	64.3±2.2	63.5±2.2	62.5±2.2	62.5±1.1	60.5±2	59.67±1.4	59±2.83	58

- **Average RPM.**

The average rpm is the average revolutions per minute at each workload over the six test sessions. During the first two workloads, which are the easy workloads (130 and 160 Watts), the average cadence sustained by CS1 were above ± 97 rpm. The average cadence decreased slightly during the next workloads (180, 200, 220, 240 and 260 Watts) with a minimum average of 88.67 rpm at 220 Watts. For the last and most difficult workload (280 Watts), an average cadence of 74 rpm was registered. This indicates that CS1 maintained a relatively high cadence throughout the test, but that the final workload was too difficult to maintain a high cadence.

- **Efficiency.**

An efficiency of 100 is seen as a perfect cycling action with no resistance applied against the cycling action. Resistance is applied during the upstroke by the weight of

the lower limb which has to move or be moved against gravity. Resistance can be relieved in two ways: 1) actively by “pulling” the pedal up (hamstring action of the same limb), or 2) passively by the force of the downward stroke of the opposite leg. A negative value for the average minimum Watts per leg, indicates that forces were applied against the pedaling action. It is interesting to note that with the easier workloads relatively more negative force was applied by CS1 to the pedals. The high cycling cadence with little resistance may result in a lack of muscle coordination, especially when taking cerebral palsy into consideration (Parker et al., 1992). The efficiency improved from a mere 65 % efficiency at 130 Watts, to an efficiency of 90 % at 280 Watts.

- **Left - Right Leg Ratio.**

This ratio is an indication of the percentage of the total Watts each leg produced during each workload. During the easy workloads, the ratio between the two legs was 36: 64, left to right leg. This improved as the workload increased and the best ratio achieved was during the last workload of 280 Watts, where a ratio of 42: 58, left to right, was achieved. This improved ratio is due not only to improved power output by the left leg (see increase in max watts), but also to a decrease in the resistance applied by the left leg (see decrease in negative minimum watts), against the down stroke force of the right leg.

Incremental Exercise Test to Exhaustion: Efficiency of Oxygen Delivery (HR).

Maximal heart rate used for the calculations during all the macrocycles was 181 bpm. The maximal heart rate achieved in the incremental exercise test to exhaustion actually varied between 179-181 bpm. Of importance is that at sub-maximal workloads, the goal was to cycle at lower heart rate (i.e. physiological intensities). The best heart rate efficiency during the First Macrocycle was in October, 2003, and the goal was achieved for that cycle. During the Second Macrocycle, best heart rate efficiency was again at competition time in March, 2004, but heart rate efficiency was better in October, 2003. During the Third Macrocycle, the July, 2004 heart rate efficiency was the best. At the VO_2 levels below 2.7 l/min, the July, 2004 heart rate efficiencies were the best overall but above 2.7 l/min the October, 2003 was the best. The training before July, 2004 focused on base training at lower intensities, which was a type of training CS1 had not focused on prior to sport performance management

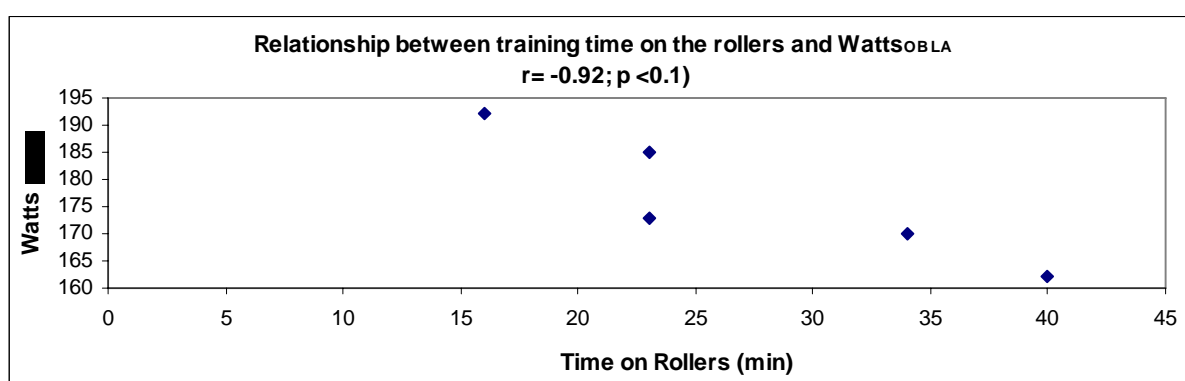
interventions. CS1 therefore responded to an increased volume of training by decreasing sub-maximal HR.

Incremental Exercise Test to Exhaustion: Respiratory exchange rate. Cycling under an RER of 1, indicates a better capacity to use oxygen to burn fat and carbohydrates to produce ATP for the cycling action. An RER of 1 was achieved at 200 Watts (83 % of W_{max}) during the October 2003 testing, and the maximum RER was 1.04. The low maximum RER indicates that CS1 was either tired, or could have been glycogen depleted. During March 2004, the Watts at RER of 1, was 220 Watts (87 % W_{max}) and during July 2004 the Watts at RER of 1, was 240 Watts (87 % of W_{max}). This is a 20 % improvement. The heart rate at RER of 1, varied between 162 – 169 bpm, except in June 2004, when it was 147 bpm. For CS1 to train or race using mostly the oxidative system he needs to train below 169 bpm.

Incremental Exercise Test to Exhaustion: Lactate Accumulation. Resting lactate concentrations are generally below 2 mmol/L in able-bodied subjects. Elevations in resting lactate concentration in CS1 confirm that CP subjects have other factors like co-contraction influencing lactate accumulation.

A negative correlation was calculated using Pearsons product moment correlation ($r = -0.92$, $p < 0.1$) between training time spent on the rollers and $Watts_{OBLA}$. This indicates that training on the rollers had a trend to negatively relate to $Watts_{OBLA}$. The more C1 trained on the rollers the lower his $Watts_{OBLA}$. Graph 44 illustrates this trend.

Graph 44. Relationship between training time spent on the rollers and $Watts_{OBLA}$.



Watts at OBLA for professional cyclists are usually around 87 % of peak sustained power output (Mujika & Padilla, 2002). In July, 2004, CS1's W_{OBLA} was only 70 % of W_{max} for CS1. Persons with cerebral palsy present with higher lactate concentrations than their

able-bodied peers at submaximal workloads due to co-contraction (ACSM, 1997). Although it is possible that cerebral palsy may have had an effect on this factor, CS1's training time (average \pm 4hr/week) was also limited relative to able-bodied cyclists.

During Macrocycles One and Two, HR_{OBLA} varied between 160-162 bpm. Therefore HR_{OBLA} during the first two macrocycles was at 88 % of HR_{max} . During the Third Macrocycle this decreased to between 148-157 bpm (82-87 % of HR_{max}). Mujika and Padilla (2002) stated that HR_{OBLA} is a good indicator of HR to be achieved during time trials shorter than 30 minutes.

Wingate Test. The Wingate 30 second anaerobic test was found to be a valid test to evaluate peak sprint power and anaerobic capacity for persons with cerebral palsy (Parker et al., 1992; Tirosh et al., 1990). Cyclists with cerebral palsy find it difficult to produce power at high speed (Parker et al., 1992). From the first round of testing to maximal performance in peak power output in October, 2004, an 18 % increase in peak sprint power output (Watts) is noticed. However since the resistance was changed in October, 2003, it is more fair to determine the improvement between October, 2003 and October, 2004 and this indicates a 10 % improvement in peak sprint power. Peak sprint power achieved by CS1 was 576.5 Watts, and the best mean sprint power was 415.20 Watts. Eight able-bodied endurance athletes, aged 29 and weighing 65 kg, were found to have a peak sprint power of 674 Watts (Finn et al., 2000). The difference between CS1 and these athletes were 14 % which is similar to the 16 % deficit in power output of the L: R leg during the PPO test. A significant trend to correlate ($r = 0.92$, $p < 0.1$) was found between mean sprint power and peak sprint power.

1-Hour Distance Trial. The 1-hour distance trial performances fluctuated a great deal. This is not usually the case for able-bodied competitive cyclists (Hawley & Stepto, 2001). There was no trend in the differences between competition time testing and non-competition time testing for best performances. This may indicate that repeatability of tests lasting this long is not good in CP cyclists. It does seem that a higher cadence of about 80 rpm average during the race and 76 rpm during the 4 % gradient and above 60 rpm for the 8 % gradient, resulted in lower heart rate intensities during the 1-hour time trial. Swain and Wilcox (1992) found that cycling uphill at a cadence of 84 rpm was the most economical, although cyclists perceived it differently. CS1 can therefore work on improving his cadence when cycling uphill.

The average heart rate achieved during all of the 1-hour distance trials was 85 % of HR_{max} . A study by Padilla et al. (2000) found that during a professional road cycling tour, the cyclists were able to cycle at 80 ± 5 % of their HR_{max} during the long time trials and 85 ± 5 % of their HR_{max} during shorter time trials. During uphill time trials the professional cyclist were only able to achieve 78 % of their HR_{max} . CS1 therefore showed he had the capacity to cycle at a high percentage of his HR_{max} during the 1-hour distance trials. Using a pacing strategy regarding power output in varying external conditions is found to be useful for performance, but the use of heart rate to assess pacing has been questioned (Atkinson & Brunskill, 2000). It is interesting to note that a constant pacing at constant external conditions has been found to be optimal, but with varying external conditions like hills or winds, adapted power pacing is more optimal (Atkinson & Brunskill, 2000).

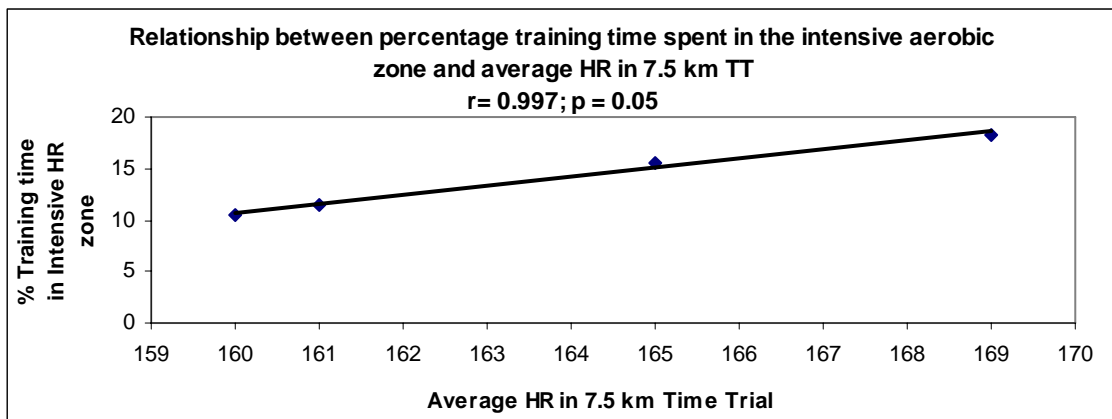
No significant correlations were found between the distance covered during the 1-hour distance trial and any of the training times in either the different heart rate intensity zones or the training time spent with a certain mode. HR is not always easy to interpret, since at fixed workloads it is better to have a lower HR, such as CS1 exhibited. However during the time trial it is desirable to work at the highest possible fraction of maximum effort, hence a lower HR is not desirable.

7.5 km Time Trial. The two best time trials were during March, 2003 and January, 2004. During March, 2003, CS1's tactics were to start fast, maintain a speed and then to increase the speed over the last kilometer. Both trials indicated a high cadence at the start, lower steady cadence during the middle part and an increase in cadence towards the end. The cadence used during March, 2003, was higher at all stages compared to January, 2004. The average cadence used during the 7.5 km time trial was 100 rpm. Research indicates that the optimal pedaling cadence is 90 rpm for trained cyclists (Neptune & Hall, 1998; Hagbert et al., 1981). CS1 therefore cycled above the optimal pedaling cadence. This can be due to either the shorter distance or a lack of muscle endurance to sustain the power output of a lower cadence but a bigger gear.

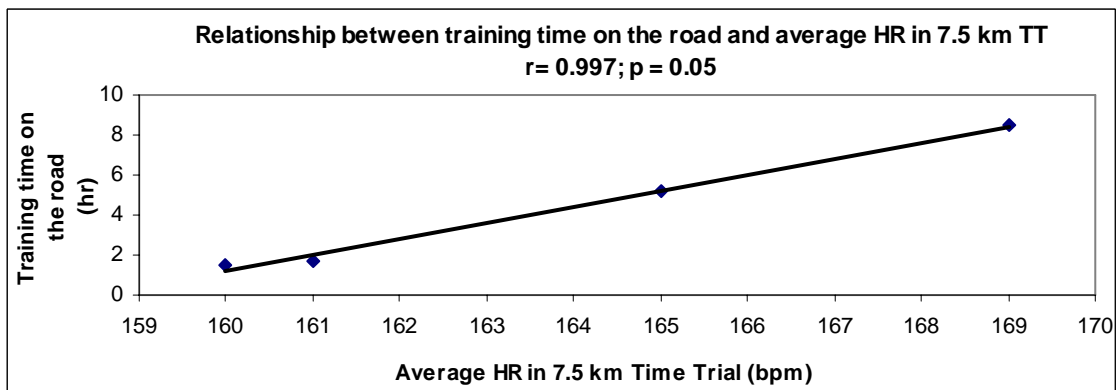
The average heart rate obtained during the test was 168 bpm during March, 2003, and 169 bpm during January, 2004. The difference in time to finish was 15 seconds, with March, 2003 the fastest at 10:30. It is important to note that tactics and gear selection can play an important role in CS1's performance in the 7.5 km time trial (De Koning, 1999; Foster et al., 1993).

Although only 4 data points were available, it was possible to look at the relationship between the average heart rate in the 7.5 km time trial and the time spent in each heart rate training zone as well as time spent training certain modes by using Pearson product moment correlations. The correlations found to be statistically significant are presented in Graphs 45 and 46.

Graph 45: Relationship between average heart rate in the 7.5 km time trial and percentage training time spent in the intensive aerobic zone.



Graph 46: Relationship between average heart rate in 7.5 km time trial and training time spent on the road.

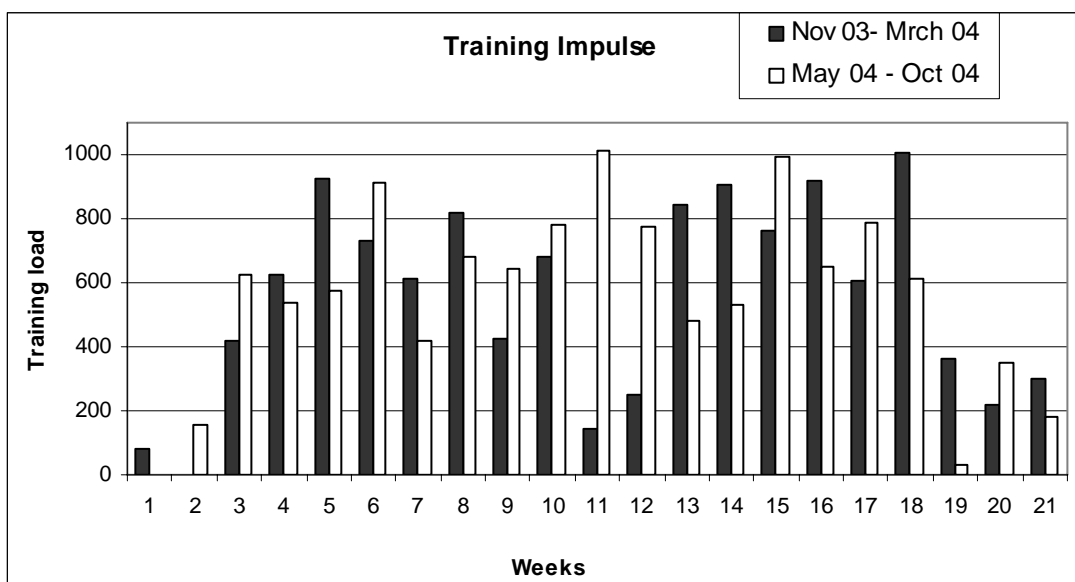


From these two graphs we can conclude that training longer on the road gave CS 1 a better ability to maintain a higher heart rate for the duration of the 7.5 km time trial. Also the intensity of training was related to the intensity he could maintain in this time trial.

Periodised Planning of Training

An interesting indicator of training load is “training impulse” (Esteve-Lanao, San, Earnest, Foster, & Lucia, 2005; Foster et al., 2001). Training impulse is calculated by multiplying the training time in each zone for each week by the fixed factor allocated to that training zone. The total of the training impulse per training zone per week is therefore the total training impulse for the week. Graph 47 is an illustration of the comparison between the training impulses for each week in Macrocycle Two and Three.

Graph 47. Training impulse for Macrocycle Two and Three for CS1



It is interesting to note the difference in training loads between the two macrocycles. The training load indicates that the maximum training load achieved by CS1 was just over 1000 and that occurred during the training camp.

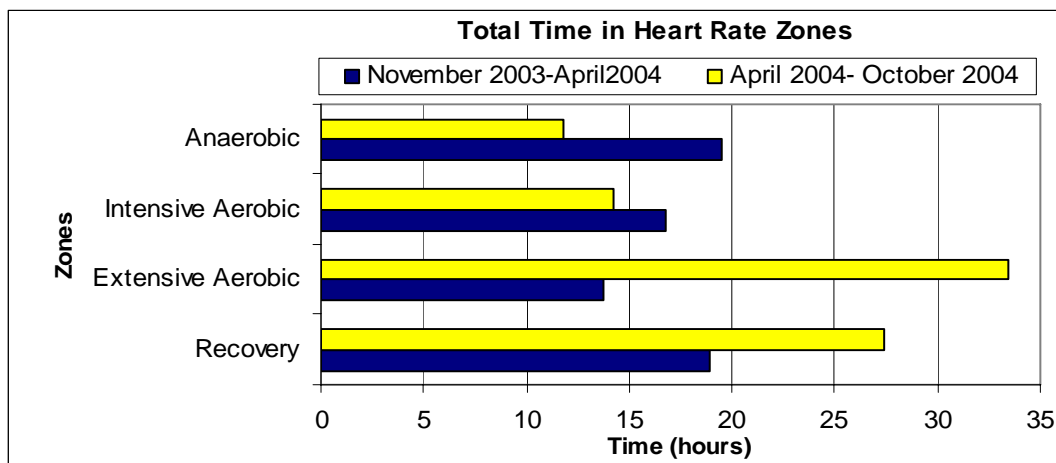
Table 30. Break down of training loads per meso-cycle for Macrocycles Two and Three for CS1

Meso-cycles	Macrocycle Two		Macrocycle Three	
	Load	% Of Total Training in Meso-cycle	Load	% Of Total Training in Meso-cycle
Weeks 1-6	2781	23.90	2805	23.90
Weeks 7-12	2929	25.18	4315	36.75
Weeks 13-18	5044	43.36	4056	34.56
Weeks 19-21	879	7.56	561	4.79
Total Training Load	11633		11737	

There was a difference of 0.9 % in total training load between Macrocycles Two and Three. This is an indication that the total training load was nearly the same. The distribution of training loads throughout the mesocycles did differ. The initial mesocycle in each macrocycle reflected the exact same percentage of maximum training load. During the second mesocycle in each macrocycle, a difference in percentage of maximum training load was 11.6%, with the higher load in the Third Macrocycle. In the third mesocycle in each macrocycle, there was an 8.8 % difference, with the Second Macrocycle reflecting a greater training load. The fourth mesocycle in each macrocycle included the tapering and competition phases. In this mesocycle, the difference between Second and Third Macrocycles was 2.8 %, with the greater load in the Second Macrocycle. It is important to note that the data for the fourth mesocycle in the Third Macrocycle is not complete due to CS1's preference not to wear the heart rate monitor during the Paralympic Games.

Time Spent in Each Training Zone

Periodisation of a yearly plan involves the manipulation of the different intensities used to train. Graph 48 is an illustration of the time spent in each heart rate zone during macrocycles two and three.

Graph 48. Training time spent in each heart rate zone for CS1 (2nd and 3rd Macrocycle)

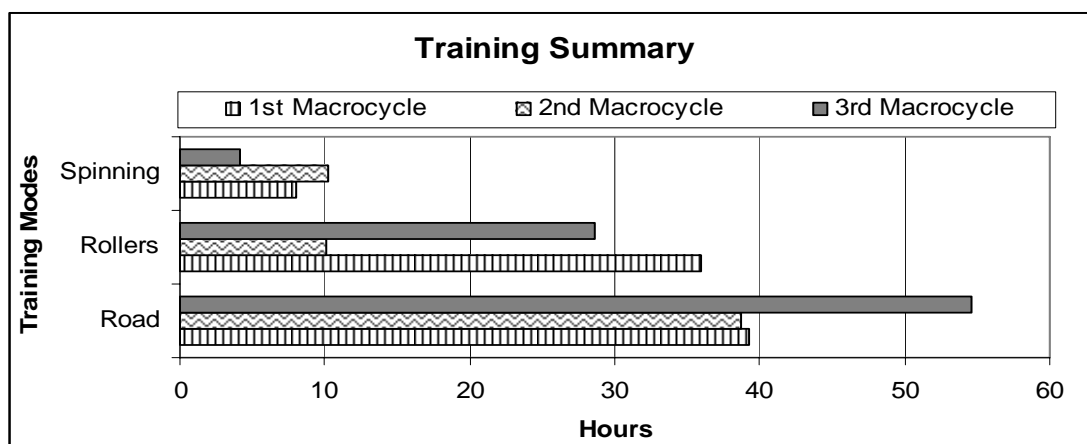
During the Third Macrocycle, CS1 spent less time training in the anaerobic zone than he did during the Second Macrocycle. However, the amount of time spent in the extensive aerobic and recovery zones was greater. This is an indication that he did more training at lower intensities in the Third Macrocycle. The time spent during the Second Macrocycle training in the anaerobic zone, was greater.

The biggest change in training time indicated in this graph was the doubling in time spent in the extensive endurance zone in the Third Macrocycle and this coincided with improvements in the incremental test to exhaustion and the best La_{OBLA} in July 2004.

Training Summary

For improved endurance training for CS1, it was found that road training was best suited for improving performance. Graph 49 is an illustration of the breakdown of training spent in the three main training modes, i.e. road training, spinning classes and roller training during the three macrocycles

Graph 49. Time spent in training modes for CS1 (First, Second and Third Macrocycles).



Time spent doing road work increased with 28 % from the First Macrocycle to the Third. A decrease in roller training is noticed during the Second Macrocycle. Training in the spinning classes was under 10 hours for each of the macrocycles.

Feedback on Training

The training log was found to be a nuisance for CS1. He did fill out his training log, but not completely. The heart rate monitor was found to be a better way of tracking the training CS1 did. CS1 did not want to monitor his training and heart rate at the Paralympic Games, due to his concern that the results might have a negative psychological effect on his performance.

Training Sessions

Training sessions were conducted generally according to the training programme that was recommended to him. Problems arose with CS1's working schedule and finding time to train, especially in winter when the sun set early. Problems finding transport had a major negative impact on getting CS1 to training venues or facilities. He does not have a license or car and is dependent on his working parents to transport him.

Training Camps

The training camp in July, 2004, seemed to have a positive influence on CS1. The fact that no working commitments could hindered his training plus he had the company of training partners, a coach for individual attention, as well as sufficient rest time seems to have had a positive effect.

Sports Medicine Services and Products

The only time that financial support was available for CS1 for sports medicine services and products was during the Third Macrocycle. Some of the sports medicine services were required from DISSA (the federation), such as a medical evaluation, nutritional evaluation, visual evaluation as well as a psychological evaluation. These assessments were conducted at the start of the Third Macrocycle.

Conclusion

To conclude, there is evidence that performance management was progressively more successful over the 18-month period of assessments and interventions. The following rating scale reflects the investigator's perceptions of the overall degree of success in managing these factors for CS1 during the course of his preparation for Paralympic competition.

Direct Factor	Score*	Reasons
Performance Assessment	4	In all three macrocycles, CS1 achieved his competition goals (medals and positions), except for the road accident at the Paralympic Games. All laboratory assessments were completed, although the Jan 2004 incremental test might not have been a maximal test. Prolonged tapering after the competition can lead to detraining and inaccurate results.
Periodised Planning of Training	4.5	An improved ability to follow a periodised plan is seen from the first macrocycle to the third macrocycle. It was considered as managed successfully.
Feedback on Training	4	Feedback on training improved from Macrocycle One to Macrocycle Three. The use of training logs was not successful, but the heart rate training feedback was.
Training Sessions	4	He did improve from Macrocycle One to Three with the implementation of the training. There was a greater emphasis on road training and CS1 was increasingly able to implement specific guidelines for training. Data indicate a higher training volume. .
Training Camp	4	The fact that CS1 had training partners, intensive coaching and no working commitments definitely was beneficial for him.
Sports Medicine Services & Products	4	The support during the Third Macrocycle was good. It is suggested that CS1 should be able to benefit from continuous Sport Medicine Support.

* Rating scale from 1 (poor) to 5 (excellent).

Chapter Five

Report of Case Study Two

Personal Background

Case Study Two (CS2) is a 21 year old male cyclist competing in Division 4. Personal information was gathered during interviews with the cyclist. His primary classification is C7, and his type of cerebral palsy is spastic. He is hemiplegic with the right side affected. As a three year old, he had surgery to lengthen his Achilles tendon.

CS2 has had professional support in the form of physiotherapy, occupational therapy and speech therapy from a young age. The occupational and speech therapy continued until the age of eleven and ten years old, respectively. Physiotherapy continued until the age of fifteen, and after that only if required. He played tennis from the age of eight to 13 and then he started to compete in athletics (field events), table tennis and cycling. At the age of sixteen he became more serious regarding his cycling and started to train for it. At the age of eighteen he competed against the seniors and a year later he started to train with a cycling coach. In 2002 he was selected to represent South Africa at the World Championships in Germany. This was the start of his international career. The following summary of his achievements at international level is evidence that he is an elite cyclist.

Year	Achievements
2002	World Championships – Germany 9 th in road race 11 th in road time trial 6 th 3000 m Pursuit 7 th 1 km Time trial
2003	European Championships – Czech Republic 13 th in road race 12 th in road time trial 8 th in 3000 m Pursuit 7 th in 1 km Time Trial
2004	Paralympics – Athens 8 th Combined Road Race and Time Trial Results 7 th 3000 m Pursuit 5 th 1 km Time Trial (own class, but 12 th combined class)

In order to determine how to support his training, a short summary of the training methods he used as well as the support system he had, was made as part of a needs analysis. The following is a summary of the preliminary information used to provide a framework for the development of a strategy to enhance the cycling performance of CS2:

Usual competitions each year	<ul style="list-style-type: none"> • South African National Championships for the Physically Disabled. • South African Able-bodied Cycling Championships. • World Championships / International event. • Able-bodied League Races
Training intensity	km/h and perceived effort
Different training modes	Gymnasium work, road training, track training, home trainer.
Bike Setup	Was set-up for him, but he adjusted it himself to fit him more specifically.
Coach	Elrick Kulsen
Coach's qualifications	None in coaching, but was a national cyclist himself.
Training facilities	Access to gymnasium, cycling track, home trainer.
Professional support	Limited Sport Science support through Stellenbosch University in cooperation with Disability Sport South Africa, when funds were available.

Modifications to CS2's Evaluation and Training

Because training must be customised at the elite level, it is necessary to modify evaluations and interventions to each specific cyclist's needs. The unique happenings in each cyclist's daily life will also modify pre-planned evaluation and training decisions.

Daily Monitoring

Daily monitoring during the First Macrocycle from April 2003 - October 2003 was based only on CS2's training log. During the Second and Third Macrocycle from October 2003 - October 2004, heart rate data were used to determine intensity, volume (duration in time) and frequency of training. CS2's daily training log was used to provide the rest of the data. Heart rate training data was received at least once a month, or more frequently when memory space was limited.

Physiological Monitoring

CS2 came for testing in the afternoon about two hours after he had lunch except the evaluation session in July, 2004 when the testing was during the morning at the training camp. The following adaptations were made to the evaluations:

1. Anthropometric measurements.

Measurements were taken on the left side of his body, due to the right side hemiplegia.

2. Wingate test.

No specific adaptations to the testing protocol. CS2 was tested against a resistance of 9.8 % of body mass.

3. Incremental test to exhaustion.

The following testing protocol was used:

Start load: 210 Watts.

Increments: First increment 30 Watts, there after 20 Watts.

Time of increments: Each increment lasted 150 seconds.

4. 1-Hour Distance Trial.

No adaptations.

5. 1 km & 3 km Time Trial.

No adaptations.

6. 7.5 km Time Trial.

Did not do the test.

Individual Interventions

Individual interventions included rehabilitation of injury during the First Macrocycle, broad layout of a periodised training plan during all cycles and feedback on training.

Group Interventions

CS2 participated in all group interventions (as described in Chapter Three).

Physiological Monitoring (Evaluation and Daily Training) First Macrocycle: April 2003 - October 2003

During the first consultation meeting with CS2, the nature of the research project was explained. CS2 expressed enthusiasm for participation and signed an informed consent form (see Appendix A). A short needs analysis regarding his access to coaching, different training modes, training programmes, and use of goal-setting in 2003 was made.

The first time period was set from the South African National Championships for the Physically Disabled held in April, 2003 to the European Cycling Championships for Persons with Disabilities in September, 2003. This period was 21 weeks.

Direct Factors Targeted during the First Macrocycle

The research question guiding this study focused on the management of selected direct factors important for sport performance for elite cyclists with cerebral palsy. The following direct factors were identified and managed in the following way:

1. **Performance Assessment:** Due to the nature of this cycle, the competition performance was evaluated for CS2 in April, 2003; July, 2003 and October, 2003. Performance assessment in the laboratory was done one week post competition in April and October and after 12 weeks of training in July. Training on a bicycle in July was only done for 4 weeks before the testing due to the time CS2 spent in rehabilitation during this macrocycle.
2. **Periodised Planning of Training:** Before this study, CS2 had never tried periodised training. A basic layout of training was given to CS2 according to the physiological goals set for the First Macrocycle.
3. **Feedback on Training:** This was introduced for the first time in his career. Explanation of how to complete the training log after each day's training was given. The training log was important for evaluating the volume as well as duration CS2 of training.
4. **Training Sessions:** The training modes available to CS2 were road cycling, spinning, roller trainers, track cycling and gymnasium work. Detailed planning of the training sessions was done by CS2's coach. He planned his own gymnasium work (he was studying to become a personal trainer).

5. Training Camps: The first training camp was the first encounter with CS2. The study was explained as well as the importance of a training log, periodisation of training and different training techniques to develop himself as a cyclist.
6. Sports Medicine Services and Products: No funding was available for support in this macrocycle. CS2 was injured at the start of the First Macrocycle and he had to pay for his own Sports Medicine support.

Goals for the First Macrocycle

The primary goal for the First Macrocycle was to prepare for the European Cycling Championships for Persons with Disabilities in Prague, Czech Republic, at the end of September, 2003. He needed to prepare for both track and road racing. CS2's preparation was hampered by a cycling accident (torn adductor muscle and a hip fracture) at the start of the First Macrocycle. The first month was spent on rehabilitation. Rehabilitation involved three sessions per week with a biokineticist and two sessions per week of aerobic training that involved arm ergometer training as well as aqua jogging during the later phases of rehabilitation. Physiological evaluation was not only used to determine the effect of training, but also to determine if CS2 would be fit to participate at the European Championships. The goals for this macrocycle were readjusted first to get CS2 injury free and back on the bicycle. After CS2 was declared fit for the European Championships, training focused on the preparation for that event.

Physiological Evaluations

The first assessment was done after competition time (April, 2003 – SA National Championships for the Physically Disabled), the second assessment was done 12 weeks after the injury and 4 weeks after CS2 started to train on a stationary bicycle in July, 2003. The third assessment was completed in October, 2003, after the European Cycling Championships for Persons with Disabilities. The changes in the laboratory data were as follows.

Anthropometry

Table 31 is a summary of the anthropometric measurements for CS2 during the First Macrocycle.

Table 31. Anthropometric measurements of CS2 (First Macrocycle)

Date	April 2003	July 2003	October 2003
Age (yrs)	20	20	20
Body mass (kg)	71.0	72.9	76.6
Height (cm)	180.3	180	180
% Fat	8.6	8.2	9.6
Somatotype	1.9 – 4.7 – 3.2	2 – 5.2 – 3	1.8 – 5.4 – 2.5

Body mass CS2 gained 1.95 kg from April to July, and an additional 3.7 kg from July to October.

Height The height of CS2 stayed constant.

Fat percentage His fat percentage only changed minimally from April – July, despite the fact that CS 2 increased his body mass with 1.95 kg. His fat percentage changed with 1.4 % from July to October, accompanied a 3.7 kg gain in body mass.

Somatotype The endomorphy component varied between 1.8 (October) to 2 (July) and the ectomorphy component between 2.5 (October) and 3.2 (April). The mesomorphic component changed from April (4.7) – July (5.2) and even more in October (5.4). In terms of circumferences, there was a 3.2 cm increase in the left arm relaxed and a 3.7 cm increase in the right arm relaxed. A 3.7 cm and 3 cm increase in the flexed arm for left and right arms respectively was recorded. The left mid-thigh circumference showed a 1.3 cm change and a change of -0.2 cm on the right side. The left calf circumference changed with 1 cm and a 0.3 cm change was found on the right side.

General The increase of 5.7 kg in body mass from April to October was due to an increase in muscle mass and fat percentage. The increased circumference of the flexed muscle is an indication that both the left and right sides increased, but the left and right leg did not increase that much. CS2's BMI of 23.6 kg/m² was higher than the recommended BMI for cyclists who are \pm 22 kg/m² (time trialers) and 19-20 kg/m² (climbers) (Lucia et al., 2001).

Incremental Exercise Test to Exhaustion

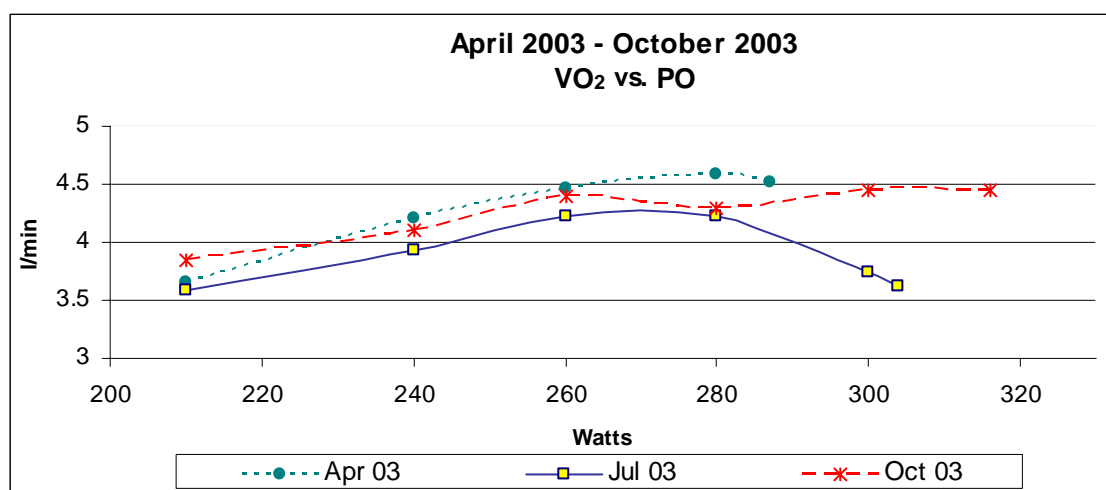
The results of this test are presented in Table 32.

Table 32. Results of the incremental exercise test to exhaustion for CS2 (First Macrocycle)

	April 2003	July 2003	October 2003
Total time of test (min:s)	11:32	12:50	14:32
VO ₂ max (l/min)	4.6	4.2	4.5
VO ₂ max (ml/kg/min)	64.7	59.6	58.2
HR _{max} (bpm)	203	201	206
Peak power (PPO) (Watts)	287	304	316
Peak power: body mass (W/kg)	4.1	4.2	4.2
Max lactate (mmol/l)	11.4	12.2	17.4
La ₂ (Watts)	68	81	41
La ₂ (HR)	162	162	141
La ₄ (Watts)	242	240	216
La ₄ (HR)	187	184	179
RER	1.2	1.2	1.1
RER of 1 (Watts)	Rest	210	242
RER of 1 (HR)	150	174	184
Time cycled at RER above 1 (min:s)	11:30	10:00	9:12

Graph 50 illustration of the efficiency of pedaling expressed as the relationship between oxygen used and work done (watts of pedaling).

Graph 50. Pedaling efficiency for CS2 (First Macrocycle)

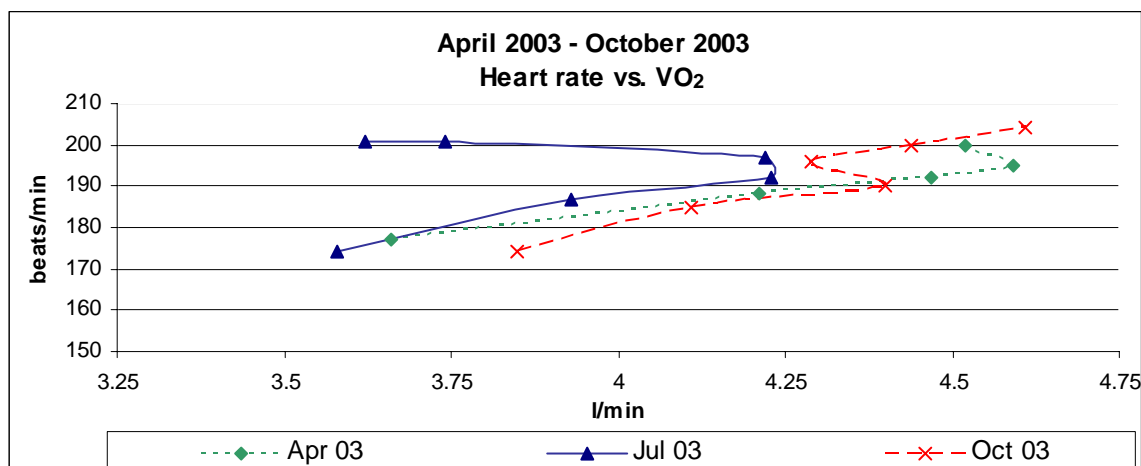


The maximal oxygen uptake is the body's capacity to transport and utilize oxygen during exercise (Powers & Howley, 2001).

- The April data indicate the least pedaling efficiency of the three tests, especially at workloads around 280 W. The highest VO_2max es were achieved in April and October, although at dramatically different PPO.
- The July testing shows a decrease in VO_2 after a peak was reached at 280 Watts. This could have been due to hyperventilation since RER was also very high. CS2 was injured and the testing in July was used to determine if he would be ready for competition in October. The improved pedaling efficiency between 240 – 280 Watts is interesting, due to the fact that CS2 was only back on the bicycle for four weeks before the testing. The rest of the endurance training was done either in the swimming pool or with an arm ergometer. He did spend a lot of time in rehabilitation doing core and torso stability exercises. It has been shown that torso stability can improve metabolic cost of pedaling, especially at low cycling cadences (McDaniel, Subudhi, & Martin, 2005).
- The October data indicate an increase of 10.1 % in PPO (Watts) from April to October but the relative PPO increased by only 3.2 %. VO_2max (l/min). Relative VO_2max (ml/kg/min) decreased from April to October from 64 ml/kg/min to 58.2 ml/kg/min, but mainly because of the change in body mass. The October testing was completed after the competition time. During competition time, tapering is the main concern and a lack of endurance type training can lead to detraining one week after competition. Bompa (1999) reported that 6-7% of VO_2max can be lost during one week of detraining.

Graph 51 illustrates the efficiency with which the heart could deliver oxygen by plotting heart rate relative to oxygen (VO_2) uptake.

Graph 51. Heart rate for CS2 (First Macrocycle)

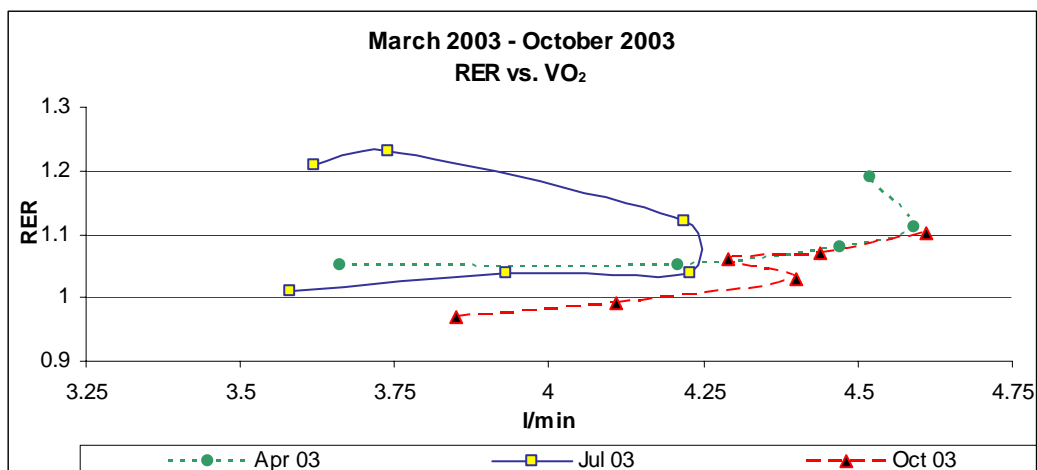


Maximal oxygen uptake is the product of cardiac output and arterial-mixed venous oxygen difference (Powers & Howley, 2001). Cardiac output is the product of heart rate and stroke volume.

- During April, CS2's maximum HR was 203 bpm. The linear increase in the heart rate was followed up to 4.6 l/min before a small decrease in VO_2 is noticeable.
- A linear plot during July is only visible until a VO_2 of 4.2 l/min. Thereafter the VO_2 decreased, with a limited increase in HR of another 10 bpm. HR_{max} for July was 201 bpm. The HR efficiency during the First Macrocycle was least efficient during July. The fact that CS2 was injured and had only four weeks of easy training on the bicycle before testing definitely influenced this result.
- The lowest heart rate for a given VO_2 up to 4.3 l/min was in October. This indicates that CS2's stroke volume at lower VO_2 was the best developed during October. Maximum HR achieved during October was 206 bpm.

Graph 52 presents the relationship between the respiratory exchange ratio (RER) and the oxygen uptake (VO_2). RER is an indication of the relative contribution of carbohydrate or fat to energy metabolism during exercise. It is the ratio of carbon dioxide output (VCO_2) to the volume of oxygen consumed (VO_2) (Powers & Howley, 2001).

Graph 52. Respiratory exchange rate for CS2 (First Macrocycle)

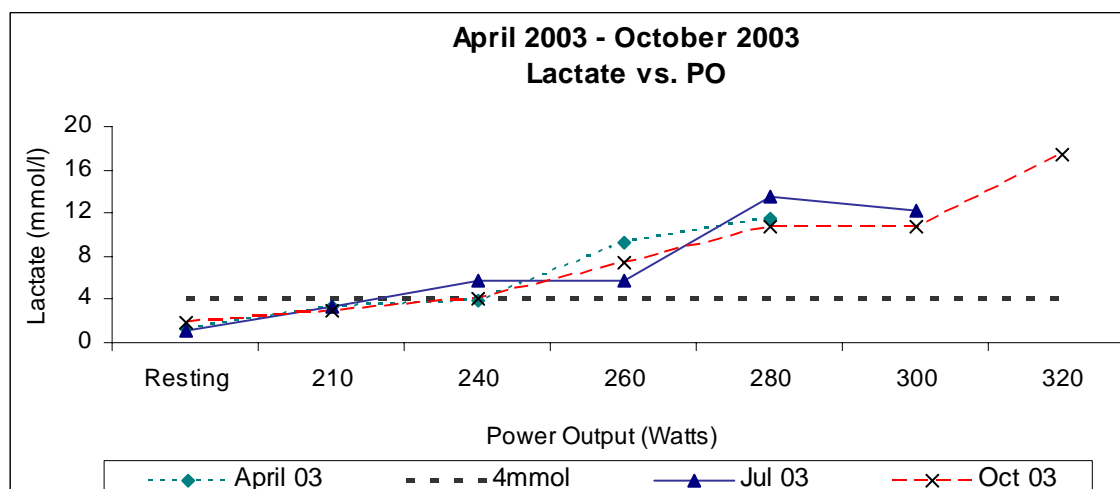


A RER under 1 indicates a desirable level in CS2's capacity to use oxidative metabolism to produce energy for the cycling action. A lower RER indicates greater fat vs. carbohydrate oxidation. In contrast, a RER above 1 indicates hyperventilation associated with anaerobic metabolism and fatigue.

- During April, CS2 started the test with a RER above 1. CS2 was therefore not well adapted to using fat oxidation as source of energy but the main source of fuel is carbohydrate with a high component of anaerobic metabolism.
- A starting RER of higher than one was also noticed during July, although it was lower than April, at the first workload. As mentioned earlier, very high RER was reported at the last 2 workloads as he then started hyperventilating that also influenced the oxygen uptake negatively.
- The October testing indicates that CS2 had developed the capacity to use fat as energy source with a starting RER lower than 1. A RER of 1 was only reached at a VO₂ close to 4.25 l/min.

Graph 53 is an illustration of blood lactate concentrations (mmol/l) at each workload (Watts) during the incremental test.

Graph 53. Blood lactate accumulation for CS2 (First Macrocycle)



A shift of the power-output lactate curve to the right is a good predictor for improved performance (Janssen, 2001). A lower lactate value at a specific workload indicates better physiological adaptation to that work intensity. CS2 has a good capacity to produce work under relatively high levels of blood lactate accumulation with a maximum of 17.4 mmol/l achieved in October. This can be due to the fact that he does a lot of track training at high intensity and that his carbohydrates depots are sufficiently filled (Janssen, 2001). During this study the onset of blood lactate accumulation (OBLA) at 4 mmol/l was used to monitor improvement.

- OBLA was achieved at 85% of PPO (242 Watts) during April.
- OBLA was achieved at 79% of PPO (240 Watts) in July.
- OBLA was achieved at 67.5% of PPO (216 Watts) in October.

This pattern is an indication that although PPO increased, the endurance training accommodating the power training was not sufficient to increase OBLA to the same percentage of maximum PPO. The Watts at which OBLA was achieved decreased from April to October, although in general the lactate power output relationship was really quite similar on all three test occasions.

Wingate Test (sprint power and resistance to fatigue)

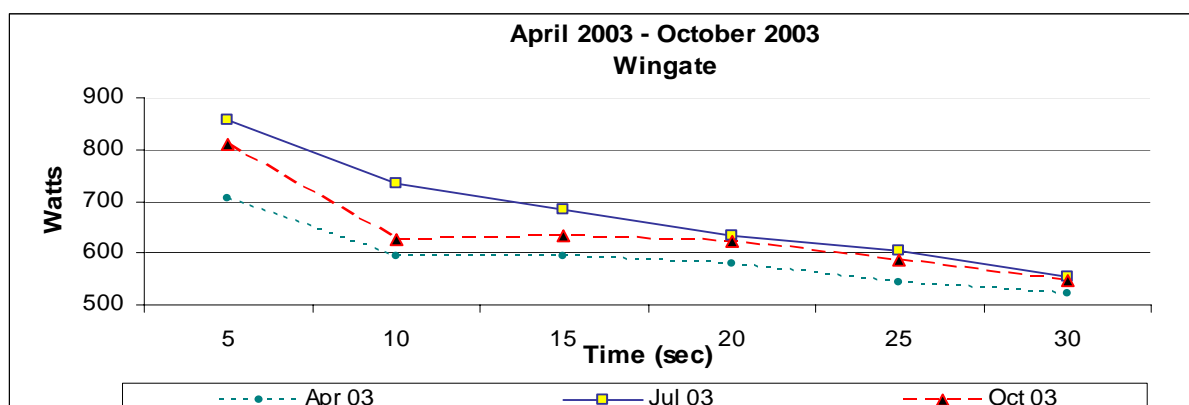
Results of the 30 second Wingate test are presented in Table 33.

Table 33. Values obtained during the 30 second Wingate test for CS2 (First Macrocycle)

	April 2003	July 2003	October 2003
Resistance	9.8 % / BW	9.8% / BW	9.8 % / BW
Body mass (kg)	70.95	72.90	76.6
Peak sprint power (Watts)	707	857	811
Relative peak sprint power (W/kg)	10.0	11.8	10.6
Avg sprint power (Watts)	590	678	638
Relative avg sprint power (W/kg)	8.3	9.3	8.3
Minimum sprint power (Watts)	520	555	549
Avg sprint power / peak sprint power (%)	83.5%	79.2%	78.6%
Fatigue index (W/s/kg)	0.09	0.14	0.11

Graph 54 is an indication of the average power output (Watts) during each 5 seconds of the Wingate test.

Graph 54. Sprint power and resistance to fatigue for CS2 (First Macrocycle)



Peak and mean sprint power are both important for tactical attacks during a road race and very important for the track events (1 km time trial and 3 km pursuit). The peak sprint power (first 5 s) is important during the start of the track events and the mean sprint power indicates the capacity to sustain high sprint power. Track racing is about power output and the capacity to maintain it.

- CS2's best peak sprint power (857 Watts or 11.8 W/kg) during this macrocycle was achieved in July after his rehabilitation period. CS2 had only been cycle training for 4 weeks on light gears. Therefore the improvement from April to July of 21.% was not

likely to be due to cycling training. The mean sprint power during July was also the best, although the fatigue index was the highest. This indicated that CS2 had good capacity to perform on the track in the 1 km TT but his 3 km pursuit might suffer due to the increased fatigue index. This improved peak sprint power in July, after no training might have been due to the fact that CS2 used a lot of jumping (due to injury to CP-leg) on his non-cerebral palsy leg as means of training.

- Peak and mean sprint power decreased from July to October with 5 % en 6 % respectively. The increased in body mass contributed to a greater decrease in relative peak and mean sprint power of 10 % and 10.6 % respectively.

1 Hour Distance Trial

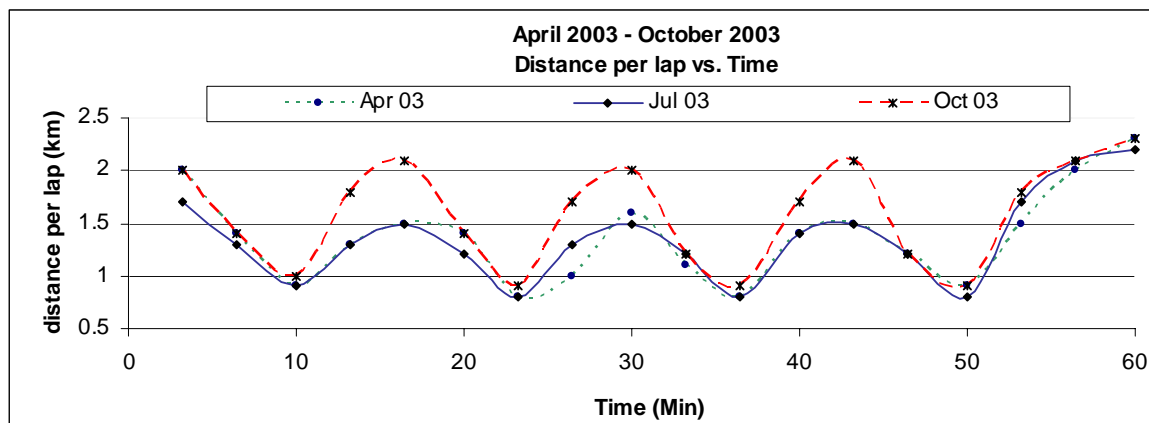
The results of this test are presented in Table 34.

Table 34. Values obtained during 1-hour distance trial for CS2 (First Macrocycle)

	April 2003	July 2003	October 2003
Total distance (km)	24.6	24.4	28.5
Avg cadence (rpm)	91±14	94±13	91±12
Total distance 4% incline (km)	5.1	4.9	5.2
Avg cadence 4% incline (rpm)	92±6	93±3	85±5
Total distance 8% incline (km)	3.4	3.3	3.7
Avg cadence 8 % incline (rpm)	69±12	73 ±3	75±4
Ave heart rate (bpm)	179±10	174±13	179±10
Highest heart rate (bpm)	192	189	190

Total Distance. Graph 55 illustrates the average split distances over time. For interpretation of the graph, each lap represents 3 minutes and 20 seconds. To simplify the interpretation of the graph, it should be remembered that the first lap was a flat distance, the second a 4% gradient hill, the third lap a 8% gradient hill, followed by 2 flat laps, before the first 4% gradient commenced again. The sequence was repeated four times. The last 10 minutes was flat. The furthest distances per lap were achieved during the flat part of the test

Graph 55. Lap Distance (km) during 1-hour distance trial for CS2 (First Macrocycle)



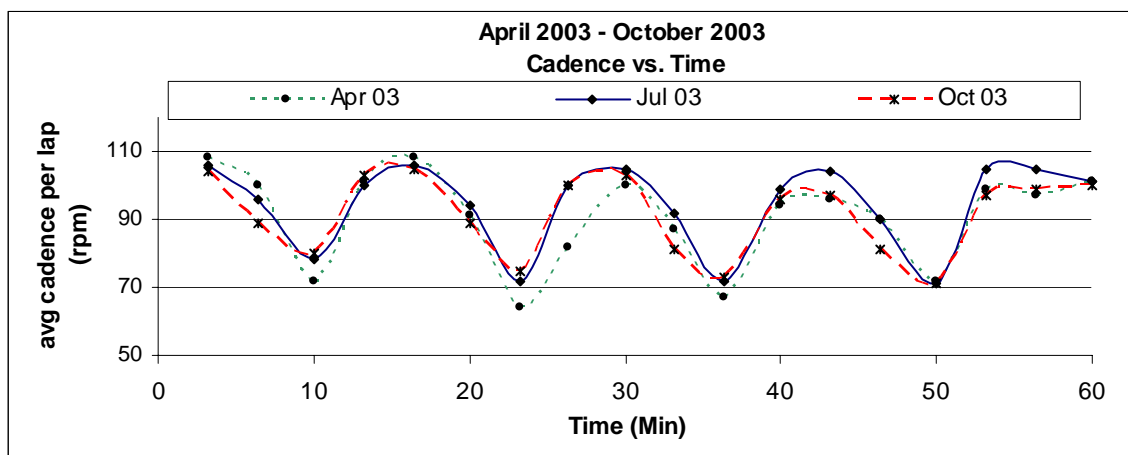
(Rationale for connecting the data points was presented in Chapter Three.)

This graph indicates the distance covered in each lap expressed relative to the accumulated time.

- During July the distance covered changed slightly with 0.2 km, with a total distance on the 4% hill 4.9 km instead of 5.1 km and 3.3 km instead of 3.4 km on the 8% hill. This indicates that the negative change in distance between April and July was all found on the hills.
- The total distance covered during October was a 16 % increase in distance since April. The total distance covered over the four 4 % gradient hill in October, was only 0.1 km more, than in April, but 0.3 km more than in June. The total distance for the four 8 % gradient hills was 0.3 km more than in April and 0.4 km more than in July. This indicates that out of the additional 3.9 km CS2 covered from April to October, 0.4 km was from the hills, and on the flat 2.5 km more was covered. From July to October, a 4.1 km improvement is recorded, with 700 m on the hills, with 3.3 km on the flat. The plots indicate a clear improvement in CS2's capacity to recover after the hills, which allowed him to cycle faster on the flat terrain. The pacing strategy in all three tests allowed for a final sprint over the last 10 minute flat.

Cadence (rpm). Graph 56 is an illustration of the average cadence over the period of time. The cadence was higher on the flat part of the race and lower on the hills.

Graph 56. Cadence (rpm) selection during the 1-hour distance trial for CS2 (First Macrocycle)



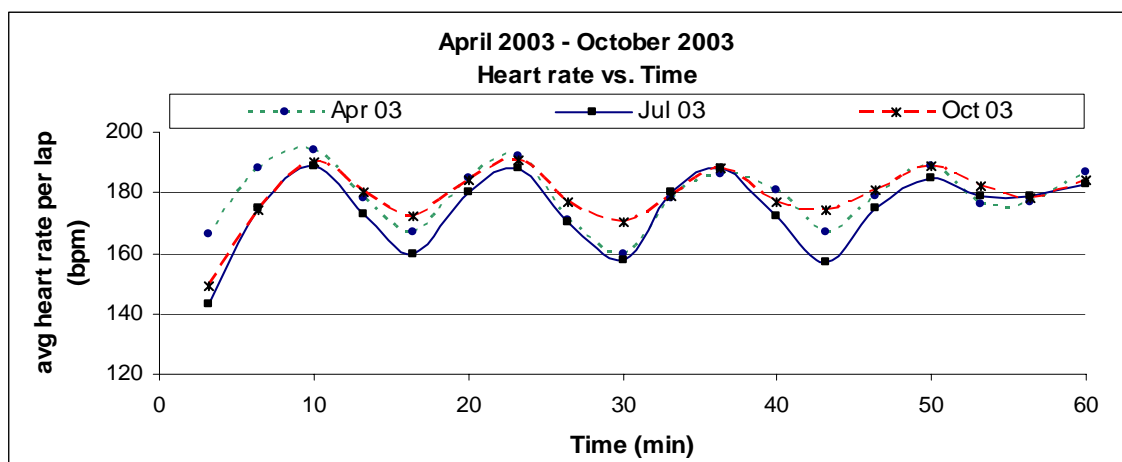
(Rationale for connecting the data points was presented in Chapter Three.)

CS2 had a similar cadence selection over the three test periods averaging between 91 and 94 rpm's. The above graph indicates that the only real difference was in the cadence selection on the hills.

- During April the average cadence on the 4 % gradient hill was 92 rpm, but the cadence selection of the 8 % gradient hill illustrates a change to 69 rpm in April.
- The average cadence for July was 93 rpm, with a cadence of 94 rpm on the 4 % hill and a cadence of 73 rpm on the 8% hill. An increase in cadence especially for the first two 4 % hills, is visible compared to April.
- The average cadence for October was 91 rpm, with a cadence of 85 rpm on the 4 % gradient hill and 75 rpm on the 8 % gradient hill. This indicates a decrease in cadence on the 4 % gradient hill from April and June, but a slight increase in cadence on the 8 % hill. This may have been an intentional strategy, or related to the better PPO.

Heart Rate (bpm). Graph 57 illustrates the heart rate (bpm) averaged per lap over the time period of the test. Heart rate is an indication of physiological intensity.

Graph 57. Heart rate (bpm) during 1-hour distance trial for CS2 (First Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

The incremental exercise tests indicated that CS2's maximum heart rates ranged between 201-206 bpm and therefore 206 bpm has been taken as HR_{max} for all calculations.

- During the April test, CS2 averaged 87% of his HR_{max} with the highest avg HR for a particular lap of 192 bpm (lap 3). The overall average HR represented 96 % of HR_{OBLA} achieved in April. The highest average HR was seen during the first 10 min.
- In July, CS2 averaged 84 % of HR_{max} , and 95% of HR_{OBLA} achieved in July. The lower average heart rate might have been an indication of lack of motivation or an inability to ride at higher intensities due to lack of high intensity training as a result of his injury.
- In October, CS2 averaged 87% of HR_{max} and 100% of HR_{OBLA} achieved in October. The October plot indicated higher physiological intensities during the flat periods of the test than recorded in either April or July.

Summary of 1-Hour Distance Trial. The only real improvement in this test was the distance covered during the flat terrain in the October testing. The change in cadence over the 8% gradient hill could have played a role in CS2's capacity to be able to keep a higher intensity during the flat period that followed the 8% gradient hill. It might also be that CS2 was aerobically better prepared to be able to maintain a 100% HR_{OBLA} as his average heart rate in October. In a study by Kenefick et al. (2002) it was found that cyclists were able to maintain a blood lactate value of 9.5 mmol during a 20 km TT. It was also found that during a 40km TT, cyclists are able to maintain blood lactate values of 7.0 -7.5 mmol/l (Kenefick et al., 2002). It is not clear (because it was not measured) what CS2's lactate concentrations might have been because an incremental test is different from a longer-lasting time trial.

1 km Time Trial

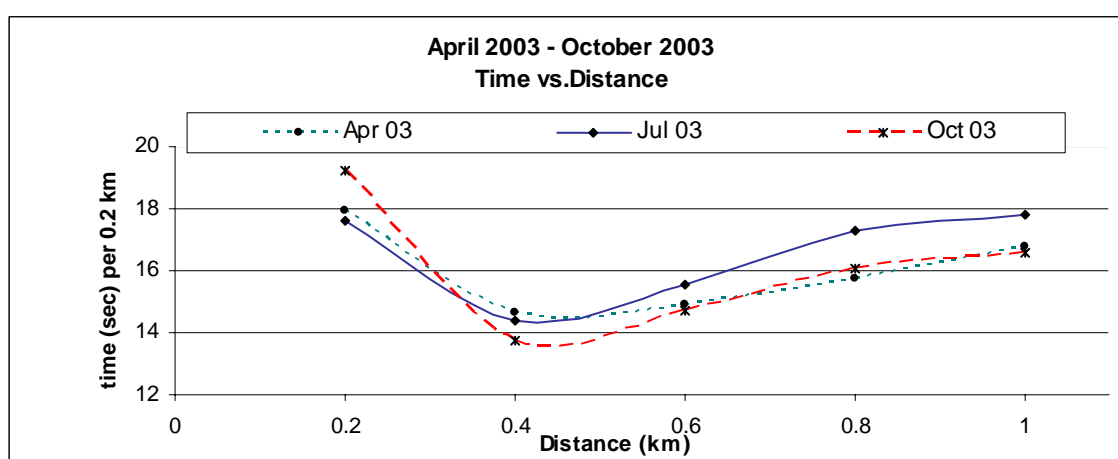
Results of the 1 km time trial are presented in Table 35.

Table 35. Results during the 1 km time trial for CS2 (First Macrocycle)

	April 2003	July 2003	October 2003
Gear selection	90	90	90
Time (min:s)	1:19.96	1:22.60	1:20.29
Avg cadence (rpm)	115±8	113±9	115±8
Avg speed (km/h)	45±4	44 ±4	45 ±6
Avg heart rate (bpm)	179±25	177±21	182±22
Highest heart rate (bpm)	197	191	196

Time / Distance. Graph 58 illustrates the time taken (s) for each 0.2 km of the 1 km time trial.

Graph 58. Time taken (s) for each 0.2 km during the 1 km time trial for CS2 (First Macrocycle)



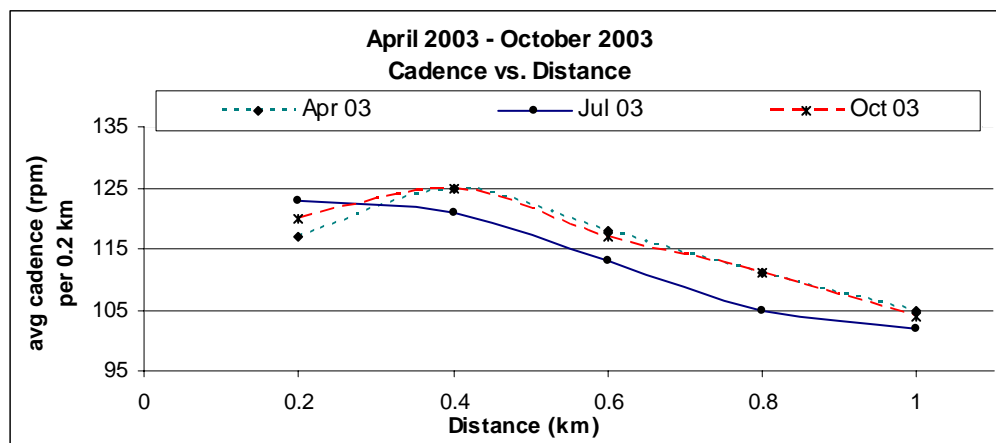
(Rationale for connecting the data points was presented in Chapter Three.)

This graph is an indication of the 1 km track time trial capacity of CS2 and the tactics he used.

- The best time of 1:19.96 was achieved during April. The tactics used by CS2 includes a slow start, due to the big gear to turn over, maximum speed achieved during the 2nd 0.2 km and then a negative change in speed towards the end. The average speed achieved in April was 45 km/h.
- July indicated the fastest start over the first 0.2 km with the greatest decrease in speed after maximal speed was obtained. Speed endurance during July was therefore limited, as well as the maximal speed obtained. The average speed obtained in July was 43.6 km/h and this is a -3 % change in average speed.
- October showed the slowest start over the first 0.2 km but the fastest speed during the 2nd 0.2 km and similar fatigue as seen in April. The average speed obtained in October was 44.8 km/h, a 3 % change since July and only 0.4 % slower than April.

Cadence (rpm). Graph 59 illustrates the cadence (rpm) averaged per 0.2 km during the 1 km time trial.

Graph 59. Cadence (rpm) selection during 1 km time trial for CS2 (First Macrocycle)



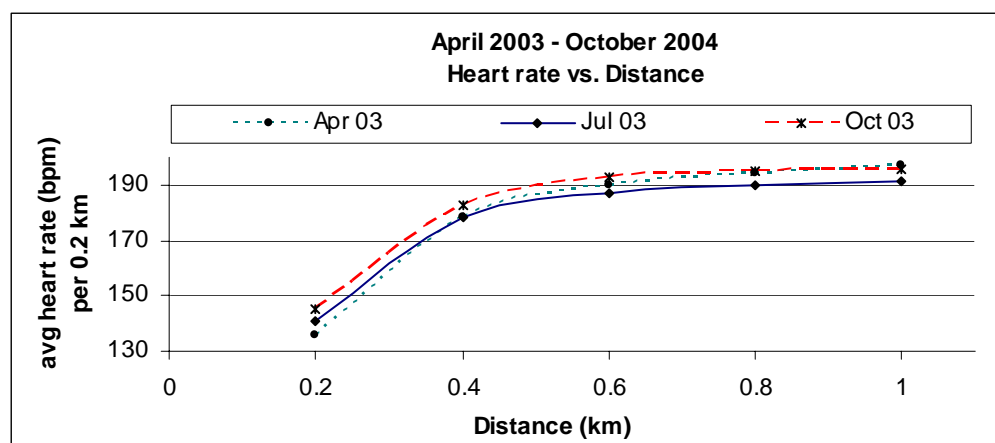
(Rationale for connecting the data points was presented in Chapter Three.)

Because no gear change is possible on a track bike, gear selection is important when considering the cadence used. During all three trials the gear selection was 90 (combination of back and front cog). The cadence graphs will therefore also indicate indirectly the speed and is essentially the inverse of Graph 59.

- Of importance is to note the higher cadence in July over the first 0.2 km. CS2 was therefore able to produce more power for the start to overcome the resistance, but his capacity to maintain the cadence during the July test was the weakest of the three tests.
- Despite the high gear, CS2 was able to maintain cadence above 115 rpm for the first 0.6 km in both April and October, and did not decrease below 100 rpm (on average) even for the last 0.2 km in all three the tests.

Heart Rate (bpm). Graph 60 illustrates the heart rate (bpm) averaged for each 0.2 km of the distance (km) covered.

Graph 60. Heart rate (bpm) during 1 km time trial for CS2 (First Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

Although heart rate during such a short and intense event is not really indicative of intensity (Powers & Howley, 2001), it is interesting to compare the different graphs.

- During April, an average heart rate of 179 bpm and a highest heart rate of 197 bpm was achieved, while in July, lower heart rate is seen for the second half of the test. The average heart rate achieved was 191 bpm and this is 6 beats lower than in April and 5 lower than in October. This is an indication that CS2 did not ride at the same intensity as in either April or October. It needs to be remembered that before July, CS2 was injured and limited training was done.
- The October graph indicates a higher heart rate and thus physiological intensity over the full duration of the test.

Summary of 1 km Time Trial. The main requirement for the 1km time trial is the capacity to maintain a high speed and therefore the capacity for muscle or speed endurance (Friel, 2003). The fact that CS2 was cycling at a lower heart rate in July, can be due to the fact that his legs could not maintain the power-output during the duration of the test. The start of the July test indicates that his peak power output was good and the best of all three tests, but he lacked speed endurance.

3 km Time Trial

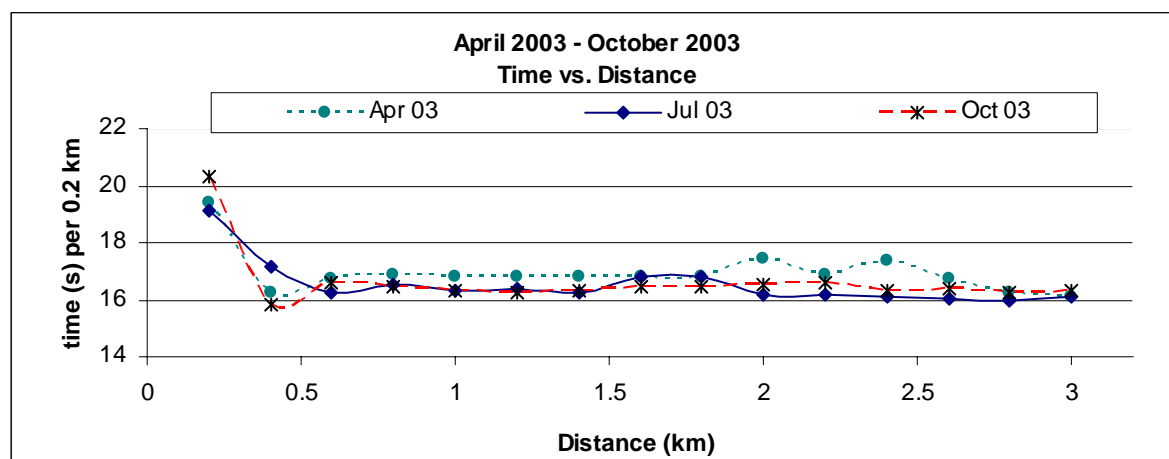
Results of the 3 km time trial are presented in Table 36.

Table 36. Results during the 3 km time trial for CS2 (First Macrocycle)

	April 2003	July 2003	October 2003
Gear selection	90	88	90
Time (min:s)	4:20.56	4:12.65	4:14.17
Avg cadence (rpm)	105±1.6	108±1	105±2
Avg speed (km/h)	43±3	44±2	43±2
Avg heart rate (bpm)	186±14	178±16	187±15
Highest heart rate (bpm)	196	190	197

Time / Distance. Graph 61 illustrates the time taken (s) over each 0.2 km during the 3 km time trial.

Graph 61. Time taken (s) for each 0.2 km during 3 km time trial for CS2 (First Macrocycle)



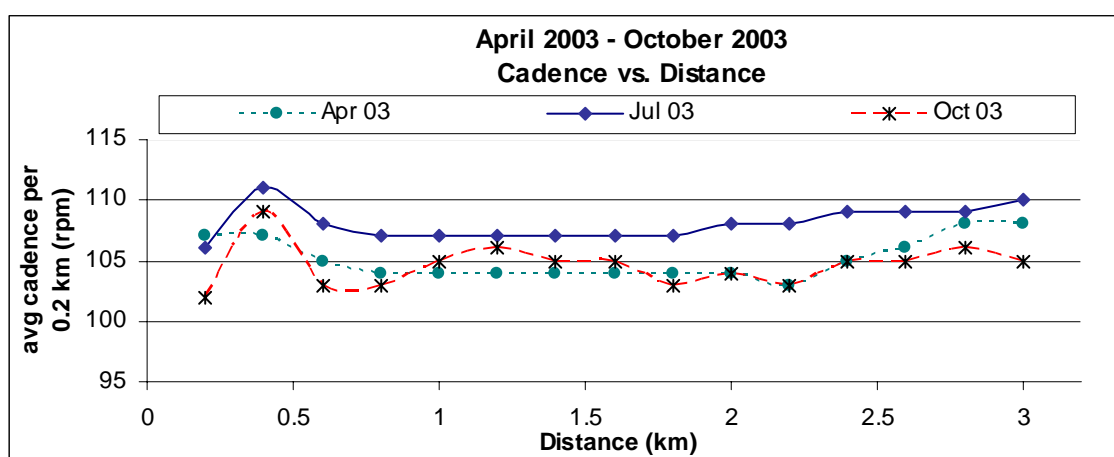
(Rationale for connecting the data points was presented in Chapter Three.)

The test simulates the riding capacity during the 3 km track pursuit as well as indicating the tactics used during the test.

- April data indicate the slowest average speed and time achieved during Macrocycle One, with the main problem being a section of slower riding between 2 and 2.6 km.
- During July, CS2 started off slower than in April or October and maximum speed was only achieved after 0.6 km, although the speed over the 3 km was better maintained and an increase in speed from the 2 km mark to the end is visible.
- October data reflects that the same tactics were used as in April, with the exception that from the 2 km mark he accelerated and maintained a higher speed for the final km, than he did in April.

Cadence (rpm). Graph 62 illustrates the cadence (rpm) averaged per 0.2 km during the 3 km time trial.

Graph 62. Cadence (rpm) selection during 3 km time trial for CS2 (First Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

Because no gear change is possible on a track bike, the gear selection is important when considering the cadence used. During the April and October the gear selection was 90, with a gear of 88 in July.

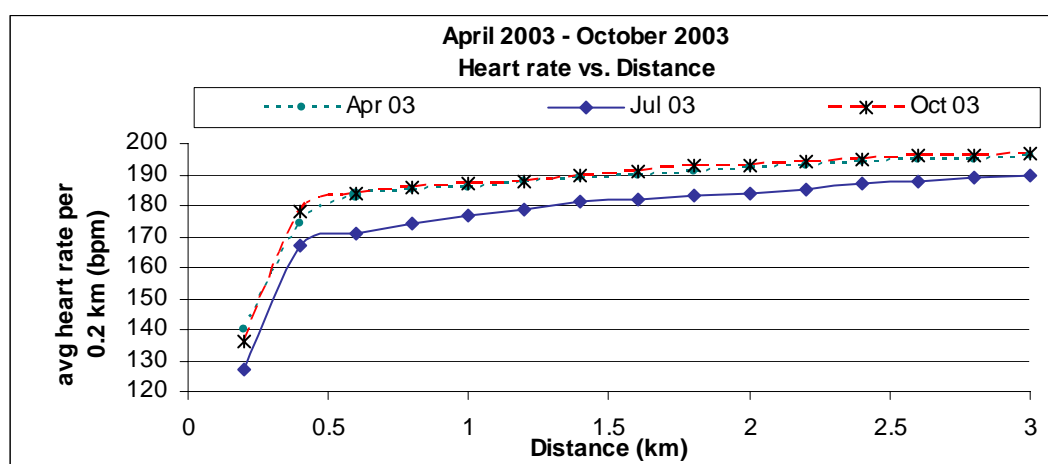
- The April cadence plot indicates that the same maximal cadence was not achieved during the first 0.5 km than during the other two trials. An increase in cadence over the last 0.8 km is visible, possibly indicating that CS2 had tactics that were too conservative in earlier parts of the trial.
- Of importance is to note the higher cadence in July over the first 0.5 km. After this a slight decrease in cadence is visible until an average of ± 106 rpm was maintained until the 2 km mark, when the cadence indicates gradual increase in cadence back to

110 rpm. The average cadence maintained during July was 108 rpm. This was possible due to the lighter gear CS2 chose to ride with, and it translated into a better time trial performance despite a lack of training.

- In October, the cadence varied continuously, with a slight increase over the last 1 km. No clear pacing strategy is observed.

Heart rate (bpm). Graph 63 illustrates the heart rate (bpm) averaged for each 0.2 km over the distance (km) covered.

Graph 63. Heart rate (bpm) during 3 km time trial for CS2 (First Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

Although heart rate during such a short and intense event is not really indicative of intensity (Powers & Howely, 2001), it is interesting to compare the different graphs.

- During April and October, the average heart rate was 186 bpm and 187 bpm respectively, with the same highest heart rate of 196 bpm.
- July shows a decrease in average heart rate of 4 % to 178 bpm. The highest heart rate achieved was also lower at 190 bpm, which was 3 % lower than in April. This was despite the better performance and may indicate that cross-training during rehabilitation added cardiovascular fitness and that the easier gear may result in lower physiological intensities and therefore a faster time.

Summary of 3 km Time Trial. The interesting fact for the 3 km time trial is that the fastest time was achieved in July, after limited training was done due to injury. The choice of the smaller gear was made because of that injury. The smaller gear allowed a faster cadence and less intensity for the fast twitch muscle fibers (Takaishi et al., 1996) due to the lower

power required at a fast cadence. But the cadence did ask for higher muscular and speed endurance. This together with motivation to prove himself for selection, could have influenced this improved performance.

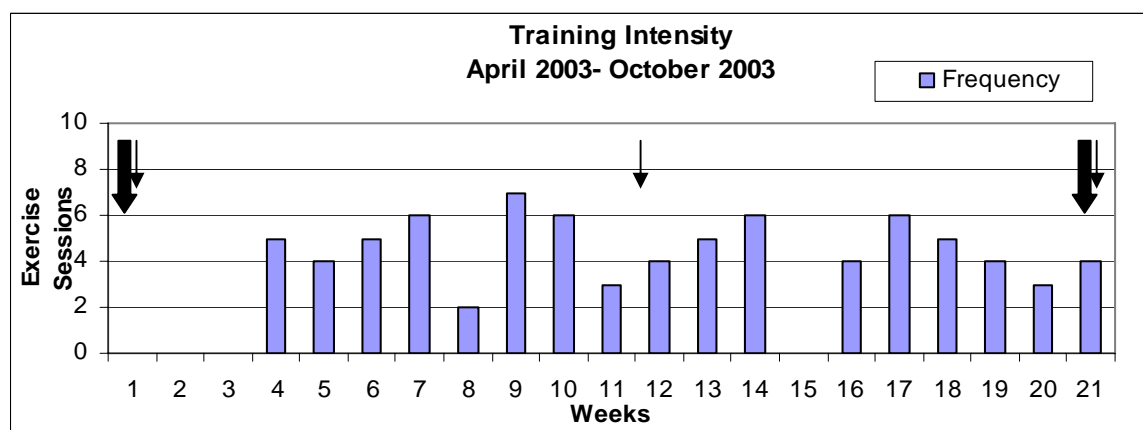
Training

During the First Macrocycle, the training logs of CS2 were used to determine his training intensity, volume, frequency and the mode of training. CS2 had a cycling accident shortly after the April testing, and due to injury was placed on a rehabilitation programme that changed his training a lot. He competed in week 21 at the European Championships in Czech Republic.

Training Frequency

Graph 64 illustrates the exercise sessions per week for the First Macrocycle.

Graph 64. Training frequency for CS2 (First Macrocycle)



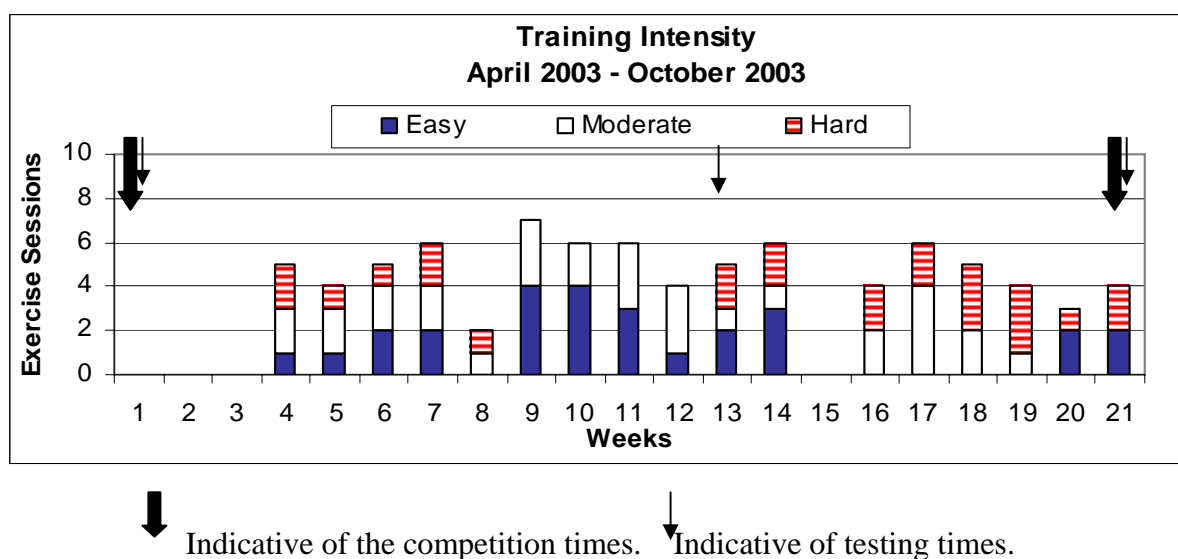
↓ Indicative of the competition times. ↓ Indicative of testing times.

For the body to adapt, it is important to keep up a minimum training frequency. Training frequency can be used to reduce training load per cycle. For the first 3 weeks CS2 was not able to train due to injury. After that he was placed on a rehabilitation programme for the injury (see last section of direct factors for full details) he achieved. At Week 9 the training started with cycling on a stationary bike and after Week 12, he started with serious bicycle training. His frequency of training was erratic.

Training Intensity

CS2 needed to indicate on the training log his perceived effort (rpe) after each training session. The training intensities were then categorized as either recovery (very easy), easy, moderate or hard sessions. His training sessions included his rehabilitation sessions. Graph 65 is an indication of the number of sessions done each week and the number of sessions at different training intensities (rpe) during each week.

Graph 65. Training intensity for CS2 (First Macrocycle)



His training intensities before Week 12 is indicative of his rehabilitation sessions that included various activities that will be described in the next section. In Week 11 he began training on his bicycle. He started to train harder at Week 13, with harder training in Weeks 16, 18 and 19. Recovery rides played a role close to competition for tapering.

Training Volume and Training Modes

CS2 noted the different training modes he used to do his training and rehabilitation in his training log. Training volume (km) was impossible to determine given that he used so many different modes of training, many of which could not be quantified in km. Hence the volume of training is expressed as duration (hours/week).

Graph 66 illustrates the different training modalities used during the First Macrocycle.

Direct Factors Targeted during the First Macrocycle

The research question guiding this study focused on the management of selected direct factors important for sport performance management. The following rating scale reflects the investigator's perceptions of the degree of success in managing these factors.

Direct Factor	Score	Reasons
Performance Assessment	4	Assessment in competition revealed that CS2 did not do as well as hoped, but taking his circumstances into consideration he did well. He did better in his track events than road events. All three laboratory assessments were completed with enthusiasm and motivation. Especially the July testing, success in testing was seen as an indicator that he was ready to train and get back on the bike. The testing was used by DISSA to support team selection.
Periodised Planning of Training	1	The plan was given to CS2, but everything needed to change after his accident. The plan was adapted to rehabilitation by the investigator together with his medical practitioner. From there on it was really a day to day adaptation and no real formal periodised plan was followed (only general guidelines).
Feedback of Training	2	The only feedback given was based on his training logs and the logs were not complete. The time span between the end of the month and when the training log was received was too long.
Training Sessions	3	The rehabilitation sessions were completed according to the plan by the medical practitioner. Gymnasium training formed part of his training, and resulted in muscle gain. Training sessions were planned by his coach.
Training Camp	4	It served its purpose of explaining the importance of planning, as well as the purpose of the study.
Sports Medicine Services & Products	5	Physiotherapy, biokinetics as well as medical practitioner support was used, but on CS2 own cost.

Score = Point out of 5, with 0 not achieved, 5 fully achieved.

Physiological Monitoring (Evaluation and Daily Training) Second Macrocycle: October 2003- March 2004

The Second Macrocycle was set after the transition phase following the European Championships in September, 2003, and lasted up to the South African National Championships for the Physically Disabled held in March, 2004.

Goals for the Second Macrocycle

The primary aim for this macrocycle was to prepare for the South African National Championship for Physically Disabled. The National Championships served as the trials for the South African Paralympic Team for Athens, 2004. It was critical to perform there at top level.

Direct Factors Targeted during the Second Macrocycle

The following direct factors were identified and managed in the following way:

1. Performance Assessment: The only competition evaluation was in March, 2004 at the South African National Championships for the Physically Disabled. Performance assessment in the laboratory was done in January after the Christmas holidays and base training period, and the week after the National Championships in March, 2004.
2. Periodised Planning of Training: A basic layout of time spent in each heart rate zone based on a maximal amount of 15 hours per week was given to CS2.
3. Feedback of Training: The training log was still used as part of the feedback, but a heart rate monitor (Polar Accurex Plus) was used as well. The training data was downloaded at least once a month, but if the watch was full data was downloaded earlier.
4. Training Sessions: The training modes available to CS2 were road cycling, spinning, roller trainers, track cycling and gymnasium work. Detailed planning of the training sessions was done by CS2's coach.
5. Training Camps: An assessment by a physiotherapist involved with persons with cerebral palsy was done, to improve aspects regarding bicycle set-up and daily living to enhance performance.

6. Sports Medicine Services and Products: CS2 made use of frequent massage sessions at his own costs.

Physiological Evaluations

The first assessment was completed in January, just after a long period of base training which included Christmas holidays. The second assessment was completed after the South African National Championships for Physically Disabled in March, 2004. The first testing was therefore not at a peak time, but the second was. The results from testing in October, 2003 (same as reported in First Macrocycle) were used to compare with the peak period of March, 2004. The physiological goal was to improve his La₄ PO values.

Anthropometry

Table 37 is a summary of the anthropometric measurements for CS2 during the Second Macrocycle.

Table 37. Anthropometric measurements of CS2 (Second Macrocycle)

Date	October 2003	January 2004	March 2004
Age (yrs)	20	21	21
Body mass (kg)	76.6	76.6	75.5
Height (cm)	180	179.5	179.5
% Fat	9.6	9.3	9.5
Somatotype	1.8 – 5.4 – 2.5	2.1 - 5.5 - 2.4	1.9 – 5.5 - 2.5

Body mass CS2's body mass stayed constant from October to January with a 1.1 kg body mass drop to March.

Height A decrease in height of 0.5 cm from October to January and March is noticed.

Fat percentage His fat percentage stayed nearly constant.

Somatotype The endo-, meso- and ectomorphic components stayed nearly the same. The only increase was noticed in the endomorphic component in January.

General His body composition stabilized and little variance are noticed.

Incremental Exercise Test to Exhaustion

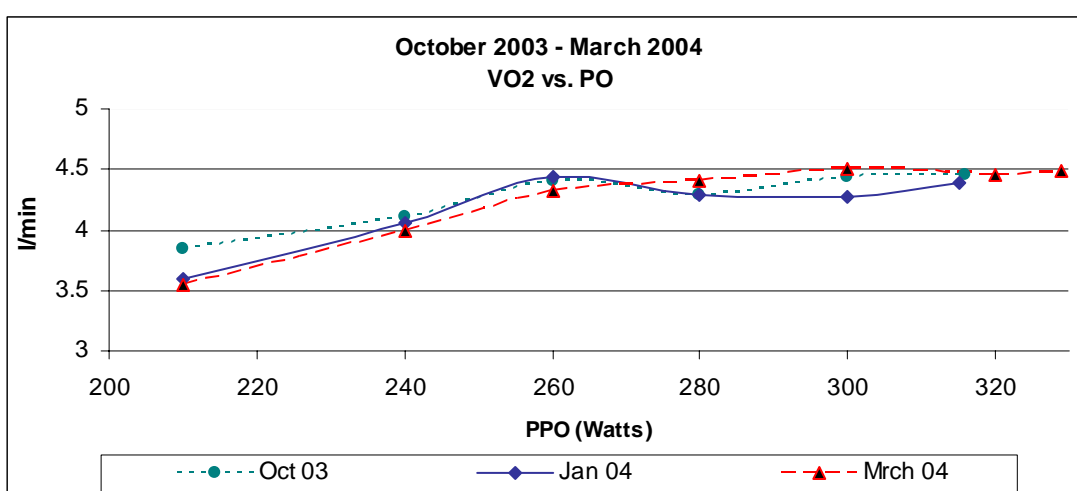
The results of this test are presented in Table 38.

Table 38. Results of the incremental exercise test to exhaustion for CS2 (Second Macrocycle)

	October 2003	January 2004	March 2004
Total time of test (min:s)	14:32	14:20	16:12
VO ₂ max (l/min)	4.45	4.43	4.5
VO ₂ max (ml/kg/min)	58.2	57.8	59.6
HR _{max} (bpm)	206	203	200
Peak power (PPO) (Watts)	316	315	329
Peak power: body mass (W/kg)	4.1	4.1	4.4
Max lactate (mmol/l)	17.4	14.2	13.7
La ₂ (Watts)	41	Start	Start
La ₂ (HR)	141	Start	Start
La ₄ (Watts)	216	223	249
La ₄ (HR)	179	171	179
RER	1.11	1.14	1.15
RER of 1 (Watts)	242	210	214
RER of 1 (HR)	184	163	164
Time cycled at RER above 1 (min:s)	9:12	11:50	13:12

Graph 67 is an illustration of the efficiency of pedaling expressed as the relationship between oxygen used and work done (watts of pedaling).

Graph 67. Pedaling efficiency for CS2 (Second Macrocycle)



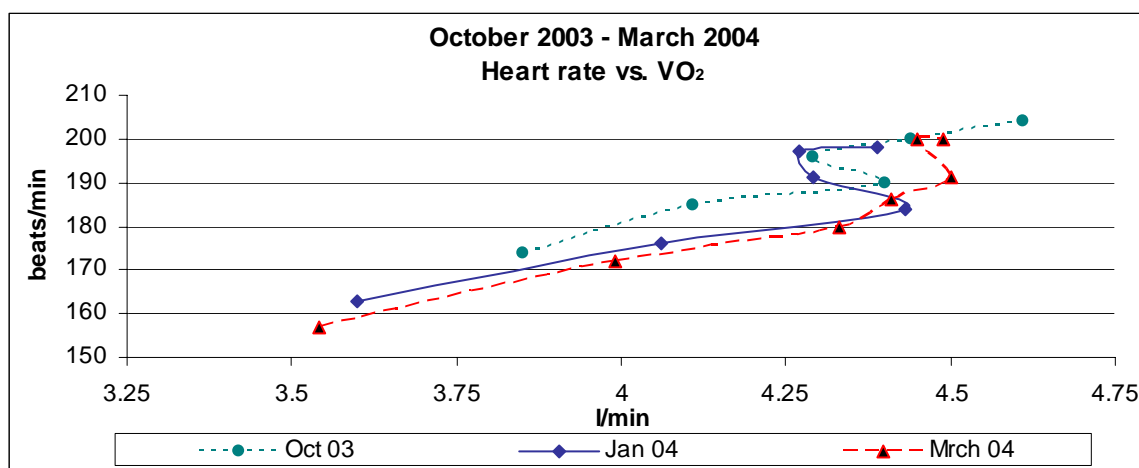
- The October graph is the same that has been used during the First Macrocycle. It is indicative that at the lower working intensities (up to 260 Watts), CS2's cycling efficiency in October was less effective than either of the other two tests.

- The January testing shows a slight negative change in VO_2 after a peak was reached at 260 Watts. His VO_2 max as well as his PPO indicates a less than 1 % decrease after October. This indicates that although his main focus up to January was to build a good base, he did not lose any power or his capacity to utilize oxygen at lower levels of resistance.
- An improved cycling efficiency is seen up to 270 Watts during the March testing. PPO of 329 Watts or 4.39 Watts/kg as well as a VO_2 max of 4.5 l/min or 59.6 ml/kg/min were achieved. This is a 4 % increase since October 2003 in CS2's PPO/kg.

CS2's training improved his cycling efficiency at workloads lower than 260 Watts from October to March. His PPO also improved, which is a good indicator of endurance performance (Hawley & Stepto, 2001).

Graph 68 illustrates the relationship between heart rate and oxygen uptake (VO_2).

Graph 68. Heart rate for CS2 (Second Macrocycle)



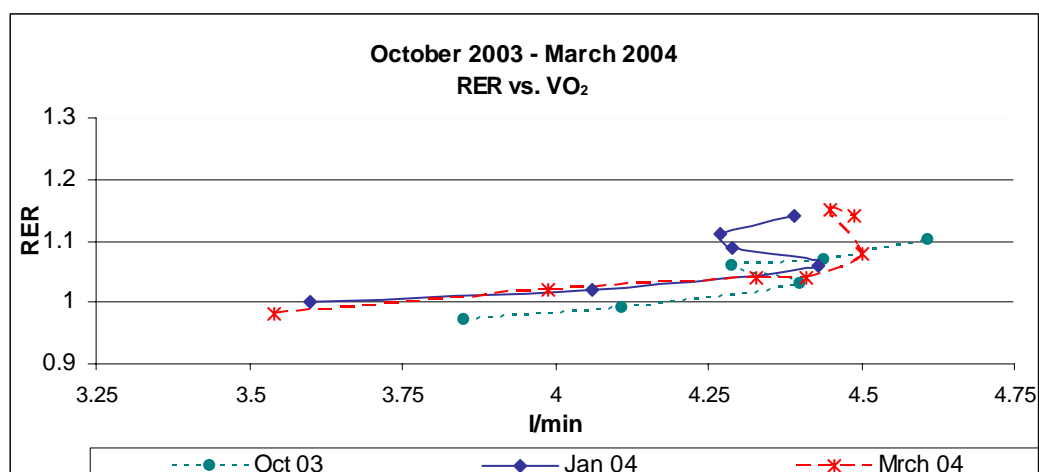
Maximal oxygen uptake is seen as the product of cardiac output and arterial-mixed venous oxygen difference (Powers & Howley, 2001). Cardiac output is the product of heart rate and stroke volume. The decrease in VO_2 max during the test can be due to a breathing deficiency.

- During October, CS2's maximum HR was 206 bpm. Both the January and March graphs show a decrease in heart rate and hence physiological intensity at all the levels of oxygen consumption.

- A linear plot in January is only visible to the peak value of 4.43 l/min was achieved. After that his VO_2 decreased. His physiological efficiency was better in January than in October.
- The March testing indicated the most improved physiological efficiency of all three tests. A maximum heart rate of 200 bpm was achieved. At all levels of oxygen consumption his heart rate was lower than for either of the other two tests.

Graph 69 presents the relationship between the respiratory exchange rate (RER) and oxygen uptake (VO_2). RER reflects the estimated contribution of carbohydrate or fat to energy metabolism during exercise. It is the ratio of carbon dioxide output (VCO_2) to the volume of oxygen consumed (VO_2) (Powers & Howley, 2001).

Graph 69. Respiratory exchange rate for CS2 (Second Macrocycle)

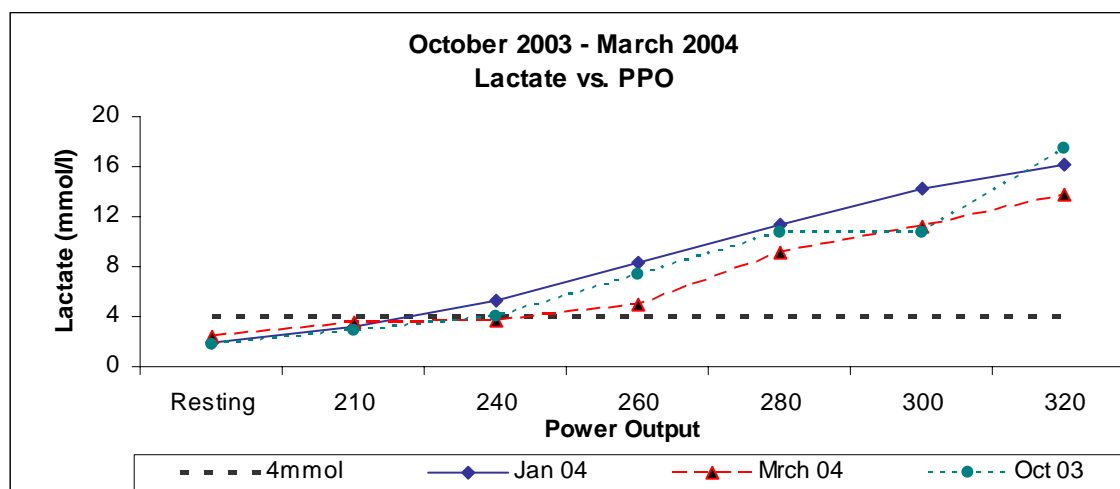


A RER under 1 indicates a desirable level in CS2's capacity to use oxidative processes to produce energy for the cycling action. A lower RER indicates greater fat vs. carbohydrate oxidation. In contrast, a RER above 1 indicates hyperventilation associated with anaerobic metabolism and fatigue.

- The October testing was the only test during the Second Macrocycle that CS2 was able to cycle the first 2 workloads under a RER of 1. His maximum RER was 1.11.
- In January, his RER at the start was already 1, and his maximum RER was 1.14. This indicates that from the start of his test carbohydrates was used a great deal as source of energy.

Graph 70 is an illustration of blood lactate concentrations (mmol/l) at each workload (Watts) during the incremental test.

Graph 70. Blood lactate accumulation for CS2 (Second Macrocycle)



A shift of the lactate power-output relationship to the right is a good predictor of improved endurance performance (Janssen, 2001). A lower lactate value at a specific workload indicates better physiological adaptation to that work intensity. CS2 had a good capacity to produce work despite relatively high levels of blood lactate accumulation with a maximum of 17.4 mmol/l achieved in October. This could be due to the fact that he did a lot of track training at high intensity and that his carbohydrate depots were sufficiently filled (Janssen, 2001). During this study, the onset of blood lactate accumulation (OBLA) at 4 mmol/l was used to monitor improvement. The recruitment of Type 2 fibers can also contribute to higher lactate values.

- OBLA was achieved at 67.5% of PPO (316 Watts) and a heart rate of 179, which is at 87% of HR_{max} , during October.
- OBLA was achieved at 71 % of PPO (315 Watts) in January. His heart rate at OBLA was 171 (83 % of HR_{max}). Although OBLA was achieved at a slightly relative higher PO, his heart rate was slightly lower.
- OBLA was achieved at 76 % of PPO (329 Watts) in March and at the same relative heart rate of 83 % of HR_{max} compared to January. His PPO improved as well as his OBLA, which indicates that he was able to ride at a higher intensity without accumulating more than 4 mmol/l of lactate in the blood. His training induced greater PPO values up to March, but also improved his ability to utilize and remove lactate out of his system.

Wingate Test (sprint power and resistance to fatigue)

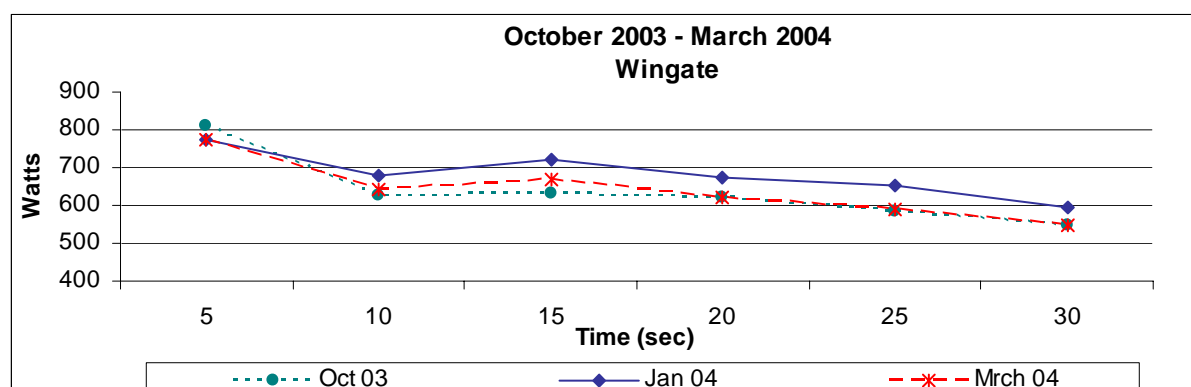
Results of the 30 second Wingate test are presented in Table 39.

Table 39. Values obtained during the 30 second Wingate test for CS2 (Second Macrocycle)

	October 2003	January 2004	March 2004
Resistance	9.8 % / BW	9.8 % / BW	9.8 % / BW
Body mass (kg)	76.6	76.6	75.5
Peak sprint power (Watts)	811	772	775
Relative peak sprint power (W/kg)	10.6	10.1	10.3
Avg sprint power (Watts)	638	682	640
Relative avg sprint power (W/kg)	8.3	8.9	8.5
Minimum sprint power (Watts)	549	594	546
Avg sprint power / peak sprint power (%)	78.6%	88%	82.6%
Fatigue index (W/s/kg)	0.11	0.08	0.10

Graph 71 is an indication of the average power output (Watts) during each 5 seconds of the Wingate test.

Graph 71. Sprint power and resistance to fatigue for CS2 (Second Macrocycle)



Peak and mean sprint power is important for tactical attacks during a road race and very important for the track events (1 km time trial and 3 km pursuit). The peak sprint power (first 5 s) is important during the start of the track events and the mean sprint power indicates the capacity to sustain maximal sprint power. Track racing is about power output and the capacity to maintain it.

- In October, CS2 the peak sprint power was the highest of the three testing periods, but the mean sprint power the lowest, which indicates the highest fatigue index.

- CS2's best mean sprint power (682.2 Watts) was achieved in January. In January, his fatigue index was good but his peak sprint power was not that good. This is understandable due to the fact that the training period before the January testing was focused more on base training and not peak sprint power. With the increase in base training the oxidative capacity of the muscles may have increased which could prevent fatigue in the second half of the Wingate test.
- His peak sprint power stayed close to the same from January to March, but his mean sprint power decreased by 6 % from January. This can be due to detraining.

1-Hour Distance Trial

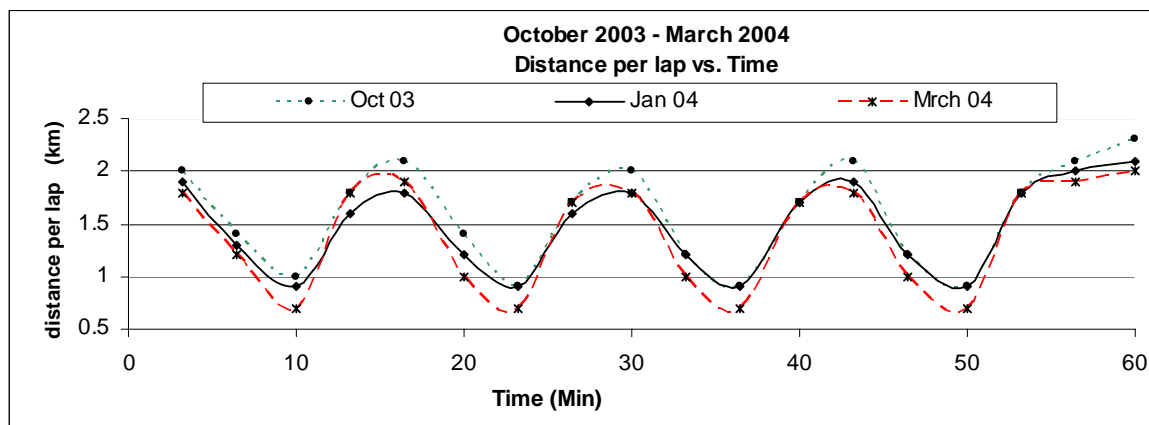
The results of this test are presented in Table 40.

Table 40. Values obtained during 1-hour distance trial for CS2 (Second Macrocycle)

	October 2003	January 2004	March 2004
Total distance (km)	28.5	26.7	25.2
Avg cadence (rpm)	91±12	90±14	74±14
Total distance 4% incline (km)	5.2	4.9	4.2
Avg cadence 4% incline (rpm)	85±5	85±4	70±6
Total distance 8% incline (km)	3.7	3.6	2.8
Avg cadence 8 % incline (rpm)	75±4	71±2	55±2
Avg heart rate (bpm)	179±10	170±10	150±8
Highest heart rate (bpm)	190	183	160

Total Distance. Graph 72 illustrates the split distance covered in each lap plotted against the total time. Each lap represents 3 minutes and 20 seconds. The first lap was a flat distance, the second a 4% gradient hill, the third lap an 8% gradient hill, followed by 2 flat laps, before the first 4% gradient commenced again and the sequence was repeated four times. The last 10 minutes was flat. To illustrate more clearly the trend, the lap data are connected. The peak distances were during the flat part of the test and the shorter distances during the climbs.

Graph 72. Lap Distance (km) during 1-hour distance trial for CS2 (Second Macrocycle)

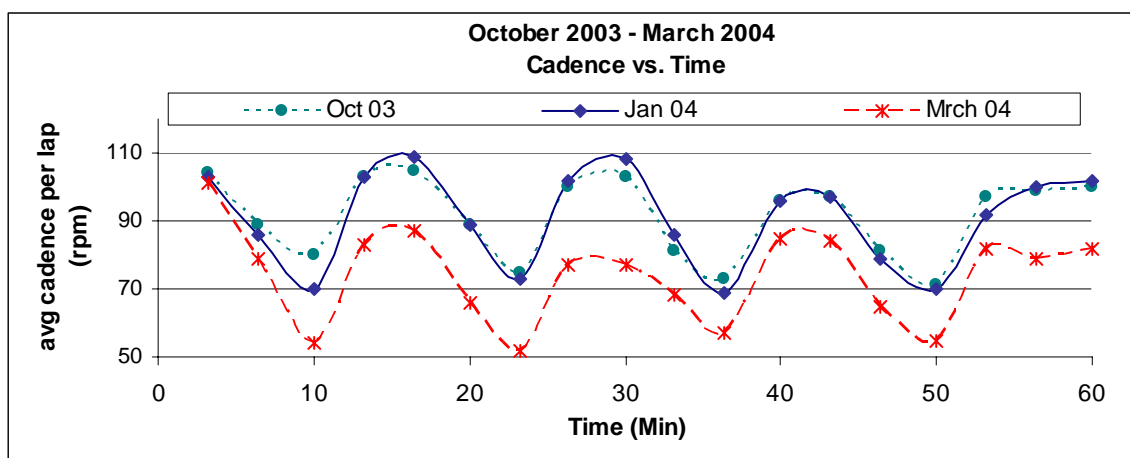


(Rationale for connecting the data points was presented in Chapter Three.)

- The distance covered in October was the furthest (28.5 km), with slightly more distance covered on the hill, but the best distances on each flat section. October shows a good final effort over the last 10 minutes.
- During January the distance covered decreased with 1.8 km, due to a -0.4 km change on the hills and a -1.4 km on the flats.
- The total distance covered during March show an 11.2 % decrease in distance since October (3.3 km). The total distance covered over the four 4 % gradient hill in October, was 1 km more, than in March. The total distance for the four 8 % gradient hills was 0.9 km more in October than in March. This indicates that out of the additional 3.3 km, CS2 covered 1.4 km more in October than March on the flat.

Cadence (rpm). Graph 73 is an illustration of the cadence (rpm) averaged for each lap plotted over the period of time. The cadence was higher on the flat part of the race and lower on the hills.

Graph 73. Cadence (rpm) selection during the 1-hour distance trial for CS2 (Second Macrocycle)



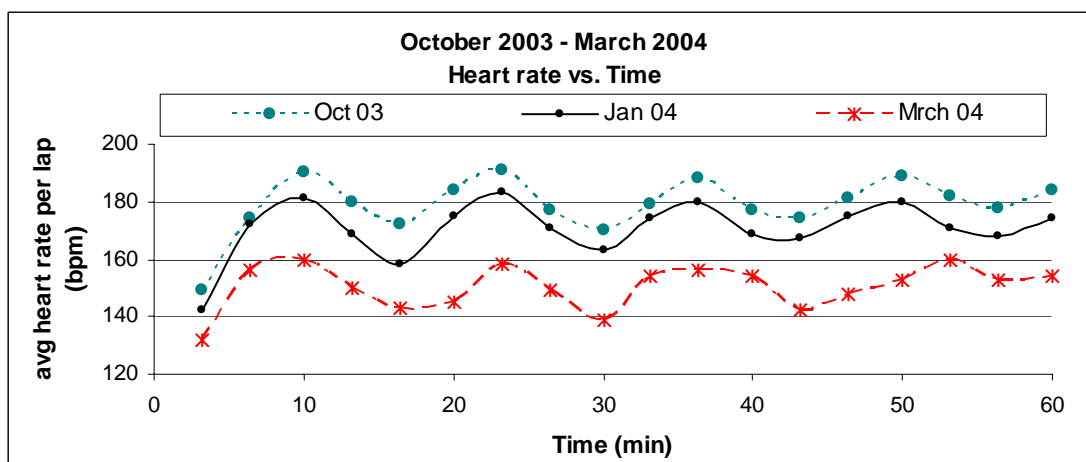
(Rationale for connecting the data points was presented in Chapter Three.)

The graph above illustrates that CS2 had a similar cadence selection in October and January, but a different selection in March.

- During October and January, the average cadence during the 1-hour distance trial was 91 rpm and on the 4 % gradient hill respectively, and 85 rpm on both tests. The cadence selection for the 8 % gradient hill was 75 rpm and 71 rpm respectively for October and January.
- Since cadences of the October test was similar to January, although a shorter distance was covered, this indicated an easier gear selection.
- The average cadence for March was 74 rpm, with a cadence of 70 rpm on the 4 % gradient hill and 55 rpm on the 8 % gradient hill. This indicated a decrease in average cadence on the flats and both hills.

Heart Rate (bpm). Graph 74 illustrates the heart rate (bpm) averaged over the time period of the test.

Graph 74. Heart rate (bpm) during 1-hour distance trial for CS2 (Second Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

The incremental exercise tests indicated that CS2's maximum heart rate was 206 bpm (October 2003) and is taken as HR_{max} for all calculations.

- In October, CS2 averaged 87 % of HR_{max} and 100 % of HR_{OBLA} achieved in October.
- In January, CS2 averaged 82.5 % of HR_{max} , and 99 % of HR_{OBLA} achieved in January. His average heart rate was 9 bpm lower than in October. But taking into consideration his % of HR_{OBLA} , he cycled at close to the same relative intensity than in October, for his body's ability to prevent blood lactate accumulation.
- CS2 averaged 72.8 % of HR_{max} and 84 % of HR_{OBLA} in March. CS2's percentage of HR_{max} as well as percentage of HR_{OBLA} , is indicative that he didn't cycle near to maximum.

Summary of 1-Hour Distance Trial. CS2 showed an 11.1 % decrease in distance cover during the 1-hour distance trial from October to March. The decrease in average cadence of 16 rpm and the decreased percentage of HR_{max} in March was indicative that motivation could have influenced his results. The highest average heart rate in October correlated with the furthest distance covered.

1 km Time Trial

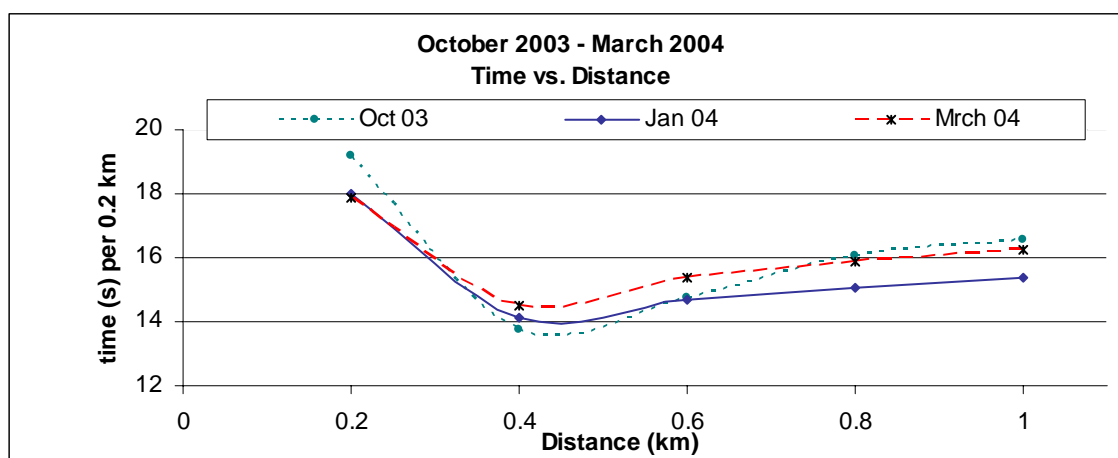
Results of the 1 km time trial are presented in Table 41.

Table 41. Results during the 1 km time trial for CS2 (Second Macrocycle)

	October 2003	January 2004	March 2004
Gear selection	90	88	90
Time (min:s)	1:20.29	1:17.23	1:19.9
Avg cadence (rpm)	115±8	120±4	113±6
Avg speed (km/h)	45 ± 6	47±4	45±3
Avg heart rate	182±22	171±25	164±28
Highest heart rate	196	188	180

Time / Distance. Graph 75 illustrates the time taken (s) for each 0.2 km lap plotted against the distance (km) during the 1 km time trial.

Graph 75. Time taken (s) for each 0.2 km during the 1 km time trial for CS2 (Second Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

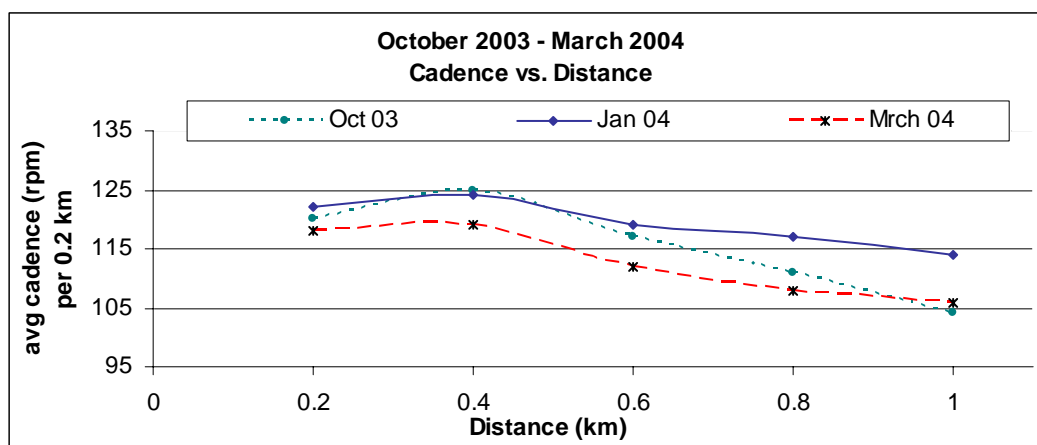
This graph is an indication of the 1 km track time trial capacity of CS2 and the tactics he used.

- CS2 had a slow start over the first 0.2 km in October but took the shortest time for the next 0.2 km.
- CS2 did the fastest 1 km time trial in January. The graph indicates the best ability to maintain speed. This could have been due to the smaller gear with which he chose to ride.

- March reflected the same fast start as in January, but the ability to sustain the speed was not possible.

Cadence (rpm). Graph 76 illustrates the cadence (rpm) averaged for each 0.2 km during the 1 km time trial.

Graph 76. Cadence (rpm) selection during 1 km time trial for CS2 (Second Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

The fact that no gear change is possible on a track bike means that gear selection is important when considering the cadence used (90 gear in October and March and 88 in January). The cadence graphs will therefore also indirectly indicate the speed.

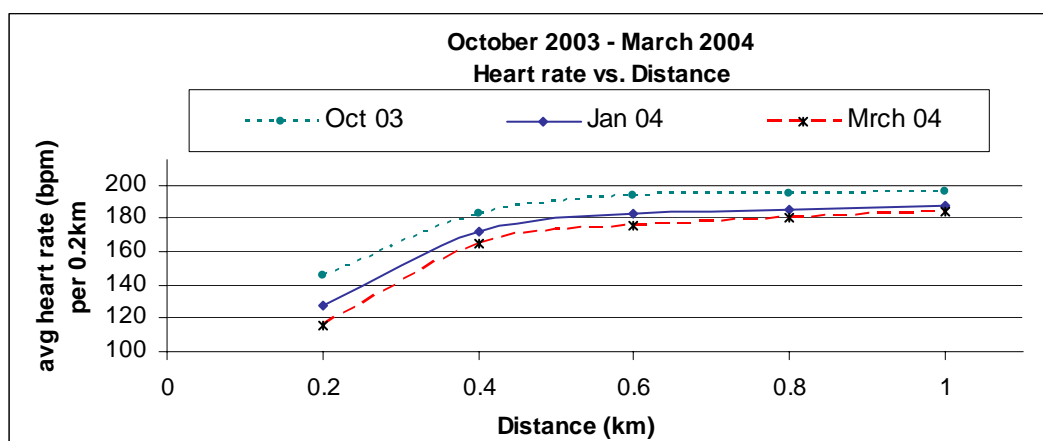
- An average cadence of 115 rpm was achieved in October. A steep negative change in cadence is seen from the peak used at the second 0.2 km to the end of the race.
- January indicated the highest average cadence of 120 rpm. A slightly lower peak cadence was achieved, but the capacity to maintain the cadence throughout the race improved. It needs to be remembered that he cycled with an 88 gear which is a smaller gear than in either October or March. This required less muscular power endurance.
- A lower average cadence in March than October was achieved, but the variance is not as great. Neither his start cadence nor his average cadence was higher than in October.

The smaller gear selection in January resulted in a better ability to maintain cadence, thus not reducing the average speed as much. This might suggest that it will be better for

CS2 to ride with a smaller gear, but maintain the cadence throughout than a large gear, that might produce a better maximum speed, but not a better average speed.

Heart Rate (bpm). Graph 77 illustrates the heart rate (bpm) averaged for each 0.2 km and plotted over the distance (km) covered.

Graph 77. Heart rate (bpm) during 1 km time trial for CS2 (Second Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

- During October, an average heart rate of 179 bpm and a highest heart rate of 197 bpm were achieved. The average heart rate during October was much higher than during January or March over the 1 km.
- The January average heart rate was 170 bpm. This was the fastest race, but a lower heart rate which is indicative that a lower heart rate was necessary to achieve a faster time.
- The lowest maximum (180 bpm) and average (164 bpm) heart rates were achieved in March.

Heart rate did not seem to be critical for performance in the 1 km time trial.

Summary of 1 km Time Trial. The main difference in the 1 km time trial is the capacity to maintain the speed and therefore muscle or speed endurance (Friel, 2003). This is seen in January where a smaller gear was selected but a faster speed was maintained. Gear selection and the capacity to cycle at a fast cadence seem to be the answer to a faster time.

3 km Time Trial

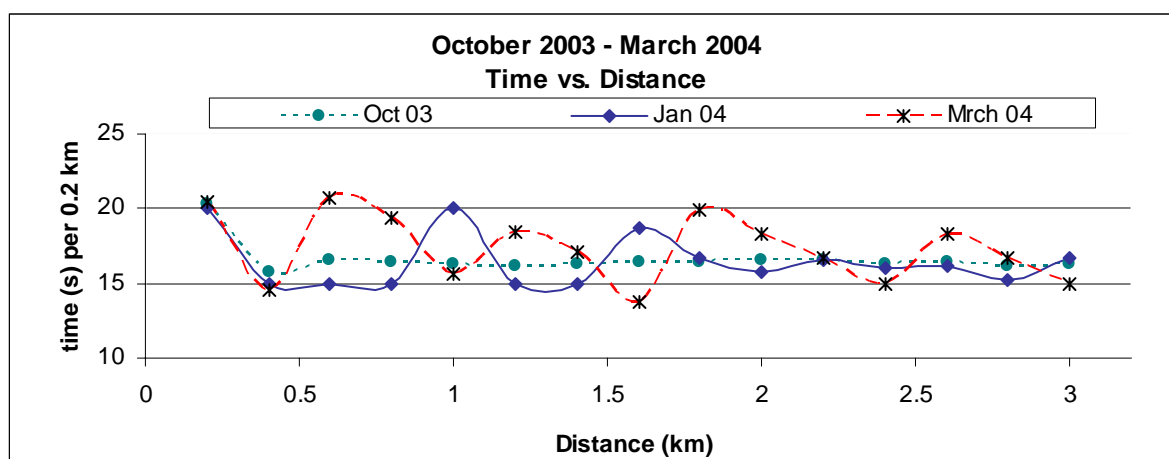
Results of the 3 km time trial are presented in Table 42.

Table 42. Results during the 3 km time trial for CS2 (Second Macrocycle)

	October 2003	January 2004	March 2004
Gear selection	90	88	90
Time (min:s)	4:14.17	4:06.6	4:19.9
Avg cadence (rpm)	105±2	111±1	102±4
Avg speed (km/h)	43±2	45±2	43±2
Avg heart rate (bpm)	187±15	177±17	172±21
Highest heart rate (bpm)	197	190	187

Time / Distance. Graph 78 illustrates the time taken (s) for each 0.2 km lap plotted against the distance (km) during the 3 km time trial.

Graph 78. Time taken (s) for each 0.2 km during the 3 km time trial for CS2 (Second Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

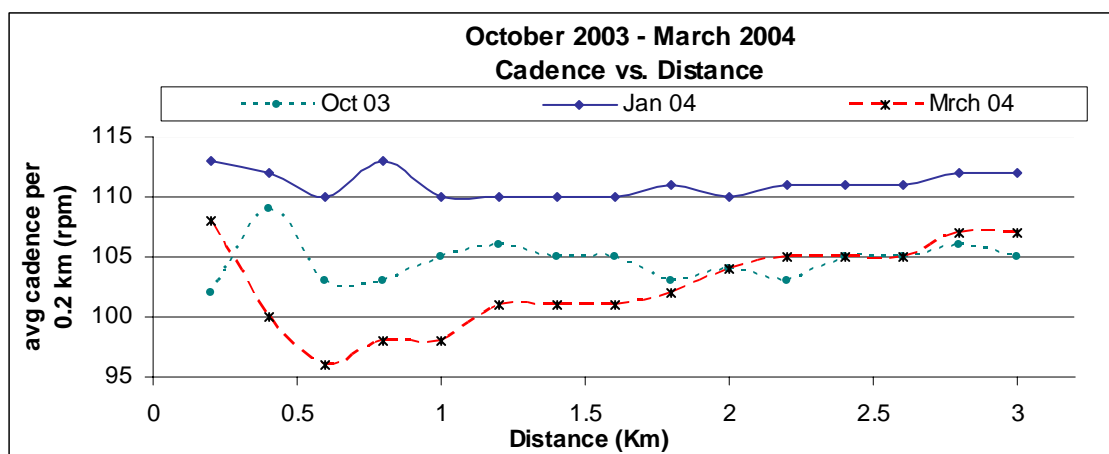
This graph is an indication of the riding capacity during the 3 km track pursuit as well as the tactics used during the test.

- October results indicated a capacity to ride at a consistent speed.
- In January, CS2 was capable of averaging a higher speed than October. This was a 3.3 % improvement. The graph shows some variability in speed with slightly slower speeds shown at the 1 km and 1.5 km mark, but after these followed 2 x 0.2 km faster laps.

- March is the slowest 3 km time trial with a average speed of 42.9 km/h. This is a decrease of 4.5 %. It also shows the most inconsistent pace.

Cadence (rpm). Graph 79 illustrates the cadence (rpm) averaged for each 0.2 km lap plotted against the distance in the 3 km time trial.

Graph 79. Cadence (rpm) selection during 3 km time trial for CS2 (Second Macrocycle)



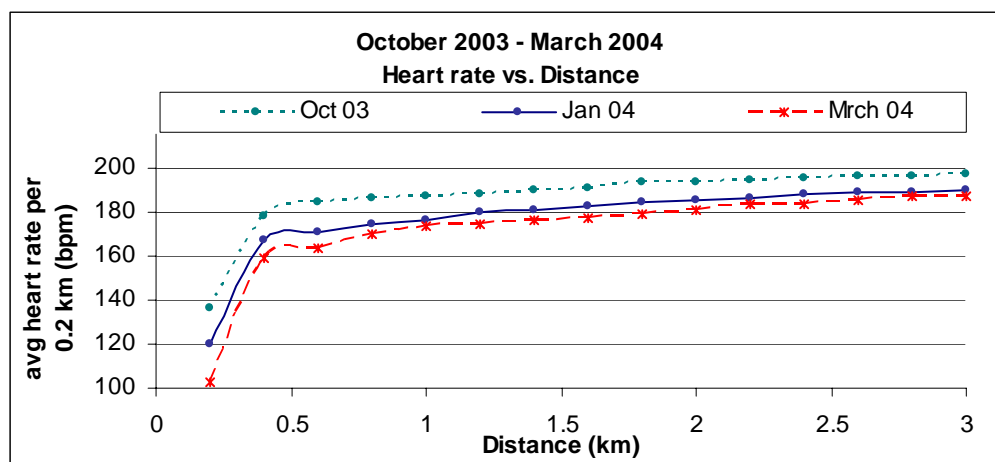
(Rationale for connecting the data points was presented in Chapter Three.)

The fact that no gear change is possible on a track bike, the gear selection is important when considering the cadence used. During the October and March the gear selection was 90, with a gear of 88 in January.

- October indicated a increase in cadence over the first 0.5 km, with sharp decrease over the next 0.2 km to a cadence of ± 103 rpm. During the October test, the cadence varied slightly the whole time.
- The January graph indicated a cadence of above 110 rpm for the whole duration of the test. The cadence was kept almost constant except for a slight increase in cadence between 0.6 km and 0.8 km.
- March indicated a cadence of above 105 rpm after the first 0.2 km, with a steep decrease until 0.6 km where the cadence was nearly 95 rpm. From there, a slow increase in cadence was visible towards the end of the race. This did not reflect a good pacing strategy.

Heart Rate (bpm). Graph 76 illustrates the heart rate (bpm) averaged for each 0.2 km lap plotted over the distance (km) covered.

Graph 76. Heart rate (bpm) during 3 km time trial for CS2 (Second Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

- The October average heart rates were higher than the other two tests, a highest of 196 bpm was achieved.
- The average heart rate achieved in January was 10 bpm lower, and the highest heart rate achieved was 190 bpm. He therefore rode at a lower heart rate intensity but at a faster average speed.
- The average heart rate intensity during March was the lowest at 172 rpm, and a highest heart rate of only 187 bpm.

Summary of 3 km Time Trial. CS2 was capable of achieving in all three 3 km time trials an average speed of 95 % or more of the average speed he was able achieve in the 1 km time trial.

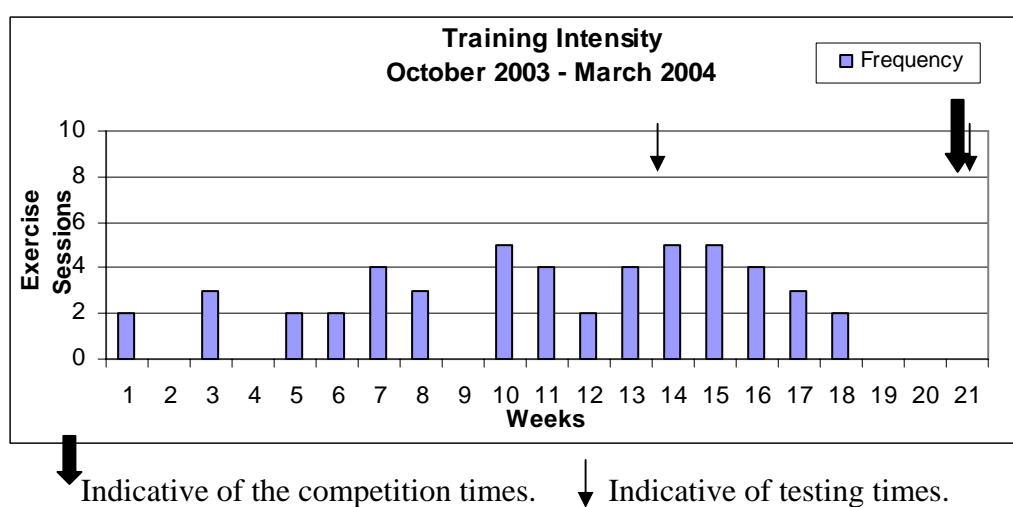
Training

Both heart rate monitor data as well as training logs filled in by CS2 were used to determine training intensity, volume, frequency as well as mode of training during this macrocycle.

Training Frequency

Graph 77 illustrates the exercise sessions per week for the Second Macrocycle.

Graph 81. Training frequency for CS2 (Second Macrocycle)



For the body to adapt, it is important to maintain a minimum training frequency. Training more frequently can be used to reduce training load of individual sessions. CS2's training frequency was a maximum of 5 training sessions per week. During the first 9 weeks, his training was very infrequent and he averaged only 2 sessions per week. From Weeks 10 – 18, the training was more frequent with an average of 4 sessions per week. Prior to the competition, the training was not reported.

Training Intensity

Graph 82 is an illustration of the time spent at different average heart rate training intensities during each week.

Graph 82. Training intensity for CS 3 (Second Macrocycle)

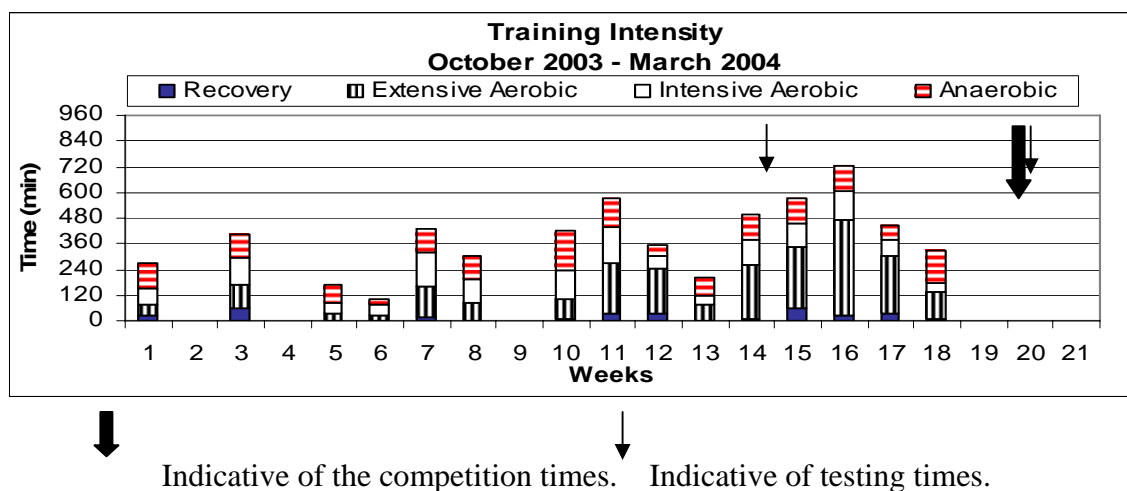


Table 43. Percentage of training time in each training zone for CS2 (Second Macrocycle)

Weeks	Recovery Zone (<70%)	Extensive Endurance (70-80%)	Intensive Endurance (80-85%)	Anaerobic (>85%)
1- 6	9.3 % (88min)	22.4 % (212 min)	31.8 % (301min)	36.6 % (347 min)
7-12	4.4 % (92 min)	36.5 % (763 min)	30.9 % (645 min)	30.9 % (589 min)
13-18	5.3 % (147 min)	51.7 % (1435 min)	18.9 % (522 min)	24 % (663 min)
19-20	Data not fully captured during this 3 weeks of training.			

Not all the training data were collected during weeks 19 - 21 and therefore that information could not be added to the graph. Data in this graph were only heart rate data. During the first six weeks of the macrocycle, training was supposed to focus on long sustained rides to build a base for future high intensity training. The limited time spent training is visible during this phase. CS2 was busy with exams and this could have influenced his training time in the zones. On average CS2 trained 2.6 hrs per week during the first 6 weeks. Of his training during this time 68.8 % was above 80 % of maximal heart rate. This indicates high intensity training. His training was therefore short and intense instead of longer less intense rides. Heart rate can be affected by various sources. During weeks 7 -12 his training was increased to an average of 5.8 hours per week which is a 123 % increase in training time. Of this training time he spent 61.8 % of his time above 80 % of HR_{max} . Weeks 13 – 18 is the pre-competition phase and it is important to increase training intensity but decrease the volume of training. His training volume increased to 7.7 hrs per training week,

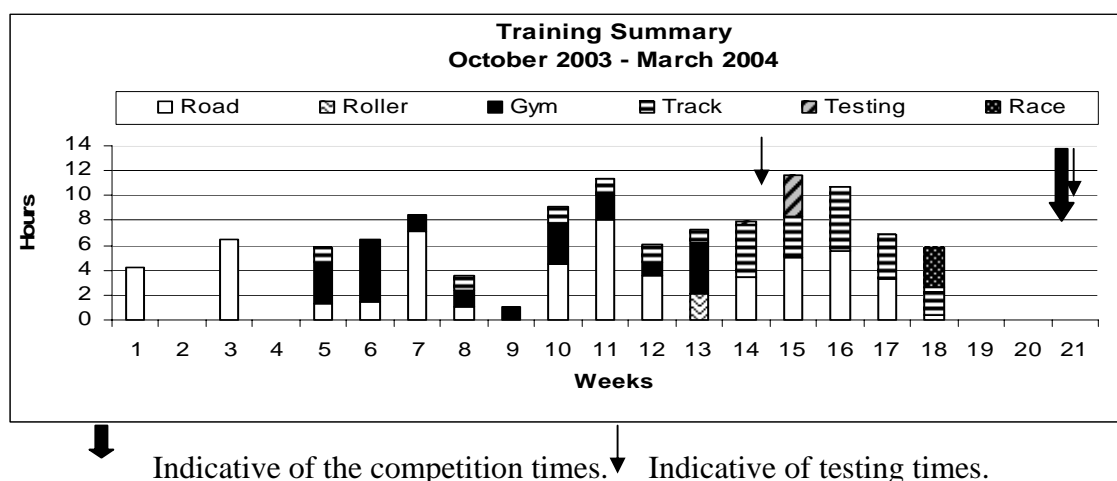
with 42.9 % of his training above 80 % of HR_{max} . No periodised training with systematic increase in training volume and intensity with subsequent recovery is noticed. The maximum training time per week was achieved in Week 16, when slightly more than 12 hr of training were reported.

Training Volume and Training Modes

CS2 noted the different training modes he used in his training log. Training volume (km) was impossible to determine given that he used so many different modes of training, many of which could not be quantified in km. The volume of training is expressed as duration (hours/week).

Graph 83 illustrates the different training modalities used during the Second Macrocycle.

Graph 83. Training summary for CS2 (Second Macrocycle)



During the first 6 weeks, CS2 spent 59 % of his training time on the road and 5 % of his training on the track. The rest of the training was done either in the gymnasium or on roller training. Weeks 7 -12 showed a 61.6% increase in time spent on the road and 13.4 % of time spent on the track. The time he spent doing other training was therefore a lesser percentage of his training. This indicated that his training became more specific. During weeks 13 -18 when training should have become very specific, his training showed a 35.6% decrease in time spent on the road and a 38.7 % increase in time spent on the track. The decrease in time spent on the road was substantial and this change might have played a role in his road racing performance. The increase in track training was indicative of high intensity training and that track racing was an important factor.

General Summary of Training

During the Second Macrocycle, the main focus was to build a good base for the rest of the year during weeks 1- 12. To achieve this, CS2's training should have been long hours with most of the training at a heart rate intensity of lower than 80% of HR_{max}. His training summary as well as his training intensity did not indicate that. Instead, especially during the first 6 weeks, he was doing little training but at high intensity. His highest average training volume was 7.7 hr and 42.9 % of training time was at less than 80% of HR_{max}. The training frequency during weeks 13-18 would have been good training during the first 12 weeks, except that a great amount of time was spent on the track. The results was discussed with the coach and cyclist.

Direct Factors Targeted during the Second Macrocycle

The research question guiding this study focused on the management of selected direct factors important for sport performance management. The following rating scale reflects the investigator's perceptions of the degree of success in managing these factors.

Direct Factor	Score	Reasons
Performance Assessment	4	The main goal for the competition was to qualify for the Paralympic Games. The goal was achieved by being included in the training squad. The laboratory tests indicate may indicate a lack of motivation in March especially in the 1-hour distance trial.
Periodised Planning of Training	1	The training intensity and training summary indicates that his periodisation of training can improve.
Feedback of Training	3	The heart rate monitor feedback made it much easier to get feedback of training. The training log was still not completed fully. The feedback of training could have been more frequent to pick up the lack of training, earlier.
Training Sessions	3	His track training sessions were planned by his coach, but the road training was as he decided on the day. The implementation of the periodisation plan at the level of the training for each day was limited.
Training Camp	4	The experienced physiotherapist's only concern was the lack of using his CP hand. She gave him exercises to do improve the use of the arm and hand.
Sports Medicine Services & Products	3	CS2 did continue to have some massages but not on a regular basis. He paid for it out of his own pocket. No other medical services.

Score = Point out of 5, with 0 not achieved, 5 fully achieved.

Physiological Monitoring

Third Macrocycle: March, 2004 – October, 2004

The Third Macrocycle was set after the transition phase following the South African National Championships for Physically Disabled held in April, 2004, until the Paralympic Games, Athens, 2004.

Goals for the Third Macrocycle

The goals for the Third Macrocycle were personal best performances at the Paralympic Games.

Direct Factors Targeted during the Third Macrocycle

The research question guiding this study focused on the management of selected direct factors important for sport performance for elite cyclists with cerebral palsy. The following direct factors were identified:

1. Performance Assessment: The main focus for this cycle was to compete at his peak at the Paralympic Games.
2. Periodised Planning of Training: A basic layout of training was given to CS2.
3. Feedback on Training: Training logs and heart rate monitor feedback was given to the investigator once a month, or when the heart rate monitor was full.
4. Training Sessions: The training modes available to CS2 were road cycling, spinning, roller trainers, track cycling and gymnasium work. Detailed planning of the track training sessions was done by CS2's coach. CS2 himself planned his gymnasium sessions.
5. Training Camps: CS2 attended a two week residential training camp at Stellenbosch University.
6. Sports Medicine Services and Products: Funding available for needs.

Physiological Evaluations

The first assessment was completed in June, just after the base training phase. The second assessment was six weeks later in July, after the two-week Paralympic Team training camp. After most of the tests in July, CS2 indicated that he could feel the fatigue in his legs. The third assessment was conducted in October, within two weeks following the Paralympic Games. Physiological his aerobic capacity still needed to improve.

Anthropometry

Table 44 is a summary of the anthropometric measurements for CS2 during the third macrocycle.

Table 44. Anthropometric measurements of CS2 (Third Macrocycle)

Date	March 2004	June 2004	July 2004	October 2004
Age (yrs)	21	21	21	21
Body mass (kg)	75.5	76.1	75.5	76.5
Height (cm)	179.5	179.5	179.6	179.6
% Fat	9.5	8.4	8.6	8
Somatotype	1.9 – 5.5 - 2.5	1.5 – 5.6 – 2.4	1.8 – 5.7 – 2.5	1.6 – 5.5 – 2.5

Body mass CS2's body mass changed from March to October with 1 kg. His body mass varied between 75.5 kg to 76.6 kg.

Height His height was constant.

Fat percentage A change of -1.5 % of body fat is seen from March to October.

Somatotype No major change in his somatotype during the Third Macrocycle.

General The negative change in body fat percentage from March to October did not result in a decrease in body mass, a small percentage (0.2 %) decrease in body fat percentage can be due to day to day variance (Jackson et al., 1988). This can be indicative that he lost fat mass, but build some muscle mass, but this is not reflected in his mesomorphy score.

Incremental Exercise Test to Exhaustion

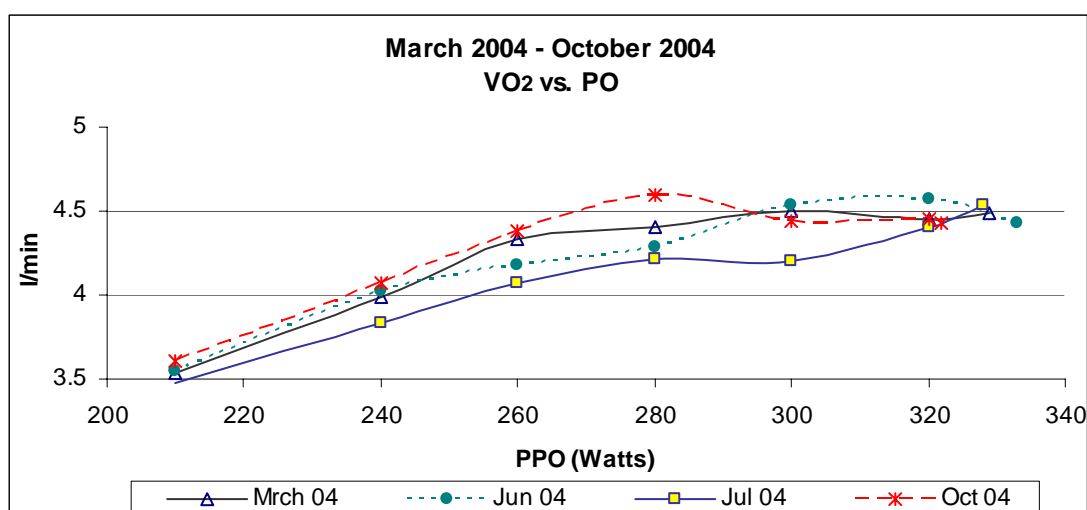
The results of this test are presented in Table 45.

Table 45. Results of the incremental exercise test to exhaustion for CS2 (Third Macrocycle)

	March 2004	June 2004	July 2004	October 2004
Total time of test (min:s)	16:12	16:47	16:04	15:14
VO ₂ max (l/min)	4.5	4.57	4.53	4.6
VO ₂ max (ml/kg/min)	59.6	60.1	60	60.1
HR _{max} (bpm)	200	201	206	206
Peak power (PPO) (Watts)	329	333	328	322
Peak power: body mass (W/kg)	4.36	4.38	4.34	4.21
Max lactate (mmol/l)	13.7	17.5	18.5	12.8
La ₂ (Watts)	Start	Start	Start	Start
La ₂ (HR)	Start	Start	Start	Start
La ₄ (Watts)	249	253	239	233
La ₄ (HR)	179	179	173	169
RER	1.15	1.07	1.07	1.07
RER of 1 (Watts)	214	280	260	210
RER of 1 (HR)	164	188	181	152
Time cycled at RER above 1 (min:s)	13:12	6:47	8:34	12:44

Graph 84 in as illustration of the efficiency of pedaling expressed as the relationship between oxygen used and work done cycling (watts of pedaling).

Graph 84. Pedaling efficiency for CS2 (Third Macrocycle)

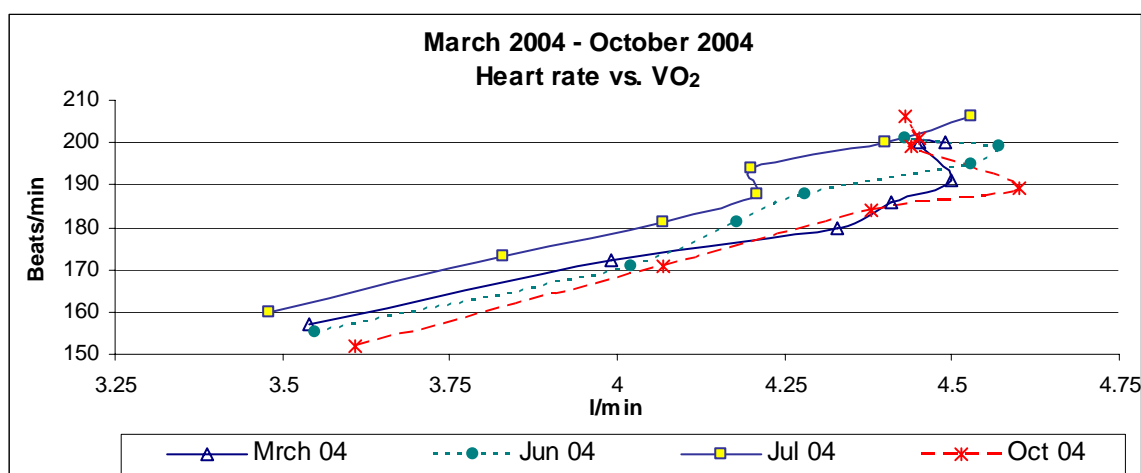


- The March graph is the same one from the last testing during the Second Macrocycle.
- June reflected a less efficient pedaling action than in March, although toward the end of the test, performance was actually very similar, as was VO₂max (1 % increase in PPO).

- The July testing, which was performed at the end of the two week training camp, indicated the best pedaling efficiency of all the tests. VO_{2max} and PPO remained similar to the other tests.
- The October testing showed the least efficient pedaling of all the testing in the Third Macrocycle. PPO changed by -1.8 %, but the VO_{2max} was not affected.

Graph 85 illustrates the relationship between heart rate and oxygen uptake (VO_2).

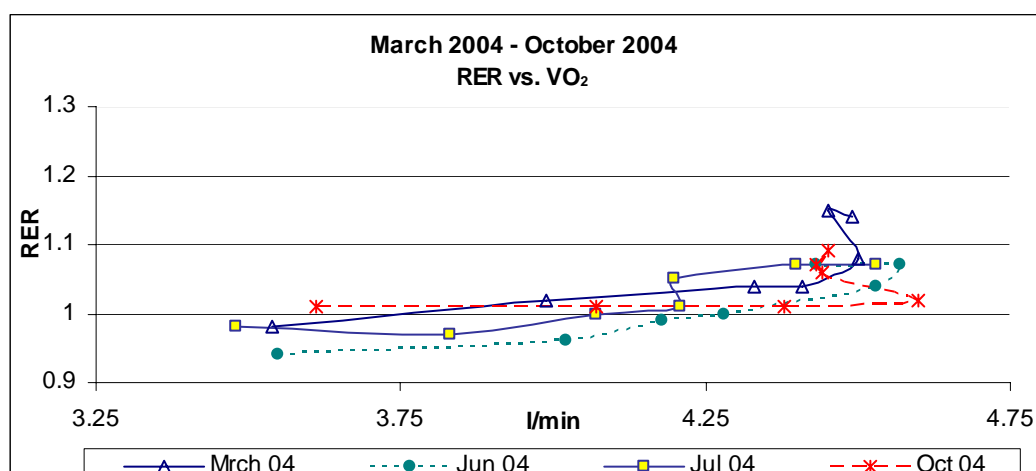
Graph 85. Heart rate for CS2 (Third Macrocycle)



- During March, CS2's maximum HR was 200 bpm, and 201 bpm was achieved in June.
- Up to 4 l/min, the heart rate was nearly the same as in March, but after that it was less efficient with a higher heart rate than in March.
- The July testing indicated the least efficient oxygen delivery of all four tests. It needs to be taken in consideration that he just completed a two week training camp. This might have influenced this. His HR_{max} during the test was 206 bpm.
- October indicated the best HR efficiency of all the graphs. A HR_{max} of 206 bpm was achieved in the test.

Graph 86 presents the relationship between the respiratory exchange rate (RER) and the oxygen uptake (VO_2).

Graph 86. Respiratory exchange rate for CS2 (Third Macrocycle)

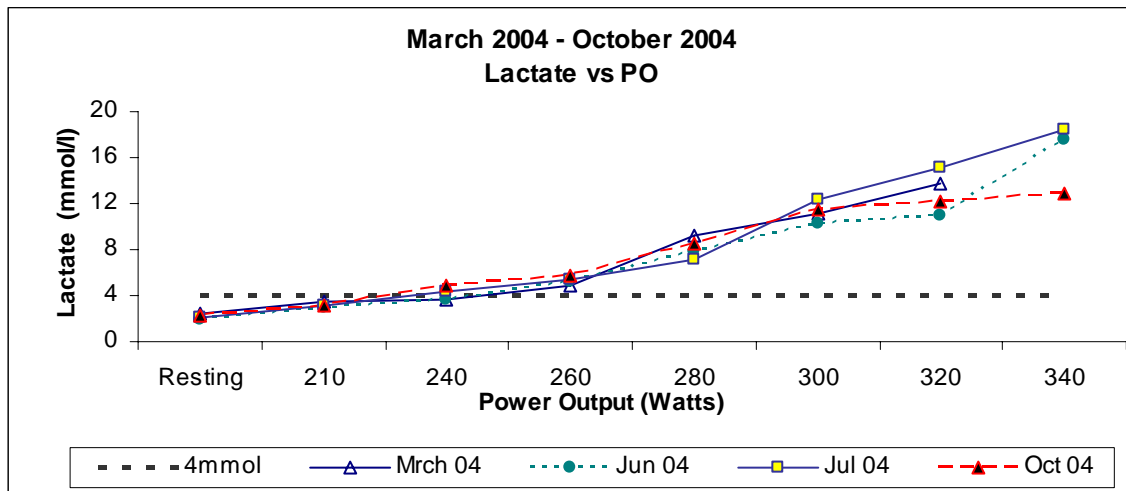


A RER under 1 indicates a desirable level in CS2's capacity to use oxygen to produce energy for the cycling action. A lower RER indicates greater fat vs. carbohydrate oxidation. In contrast, a RER above 1 indicates hyperventilation associated with anaerobic metabolism and fatigue.

- During March, a maximum RER of 1.15 was achieved and CS2 was able to ride above 1 for 13:12 minutes. He reached a RER of 1 at 214 Watts and 164 bpm.
- June indicated the best ability to utilize the fat oxidation system as source of energy, with a RER of 1 only at 280 Watts and 188 bpm. His maximum RER was only 1.07. The focus of the base training before this testing was to adapt the body to be able to utilize the oxidative system.
- During July, a RER of 1 at 260 Watts and 181 bpm indicates a decrease in the ability to utilize fats. The maximum RER remained 1.07. The decrease might be due to the fact that he was not rested before the testing, or had greater carbohydrate availability.
- His ability to utilize the oxidative system decreased toward October. This might be due to the focus on high intensity training and a lack of extensive endurance training that supports the training of the oxidative system. A RER of 1 was achieved at 210 Watts and 152 bpm.

Graph 87 is an illustration of blood lactate concentrations (mmol/l) at each workload (Watts) during the incremental test.

Graph 87. Blood lactate accumulation for CS2 (Third Macrocycle)



- OBLA was achieved at 76 % of PPO (329 Watts) during March.
- OBLA was achieved at 76% of PPO (333 Watts) in June.
- OBLA was achieved at 73 % of PPO (328 Watts) in July.
- OBLA was achieved at 72 % of PPO (322 Watts) in October.

OBLA as percentage of PPO decreased towards competition time. CS2's starting lactate was never lower than 2 mmol/l. His heart rate at OBLA ranged between 169 bpm – 179 bpm.

Wingate Test (sprint power and resistance to fatigue)

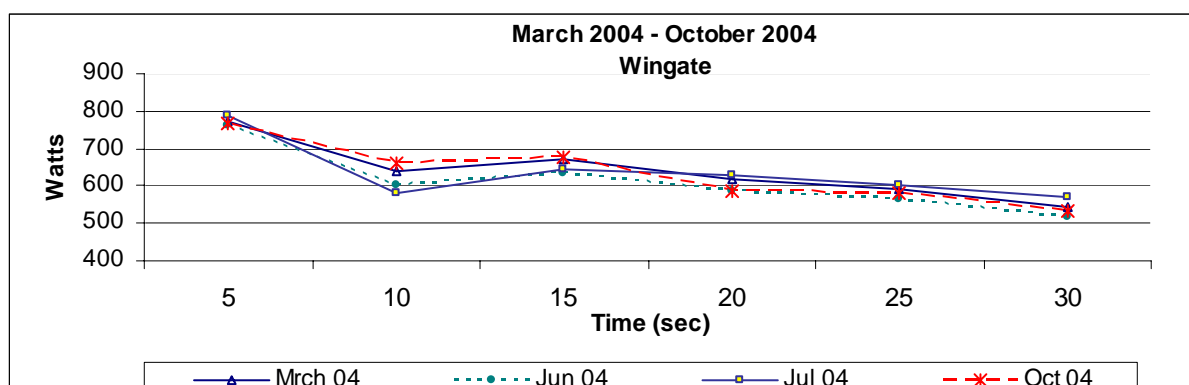
Results of the 30 second Wingate test are presented in Table 46.

Table 46. Values obtained during the 30 second Wingate test for CS2 (Third Macrocycle)

	March 2004	June 2004	July 2004	October 2004
Resistance	9.8 % / BM	9.8 % / BM	9.8 % / BM	9.8 % / BM
Body mass (kg)	75.5	76.1	76	76
Peak sprint power (Watts)	775	761	786	769
Relative peak sprint power (W/kg)	10.3	10.0	10.34	10.12
Avg sprint power (Watts)	640	611	636	633
Relative avg sprint power (W/kg)	8.48	8.02	8.36	8.34
Minimum sprint power (Watts)	546	517	572	532
Avg sprint power / peak sprint power (%)	82.6%	80.3%	80.9%	82.4%
Fatigue index (W/s/kg)	0.10	0.11	0.09	0.10

Graph 88 is an indication of the average power output (Watts) during each 5 seconds of the Wingate test.

Graph 88. Sprint power and resistance to fatigue for CS2 (Third Macrocycle)



- The mean sprint power in March was the best of the last four tests.
- Peak sprint power decreased with 1.8 % towards June, and the mean sprint power with 4.6 %. This is indicative that the training did not focus on improving the peak and mean sprint power.

- During July, the peak sprint power increased to a maximum during the Third Macrocycle of 786 Watts and the means sprint power was only 1 % less than the best (achieved in March). The training improved his peak power and mean power from June to July.
- October data indicated a negative change in peak sprint power, but similar in mean sprint power at competition time.

1-Hour Distance Trial

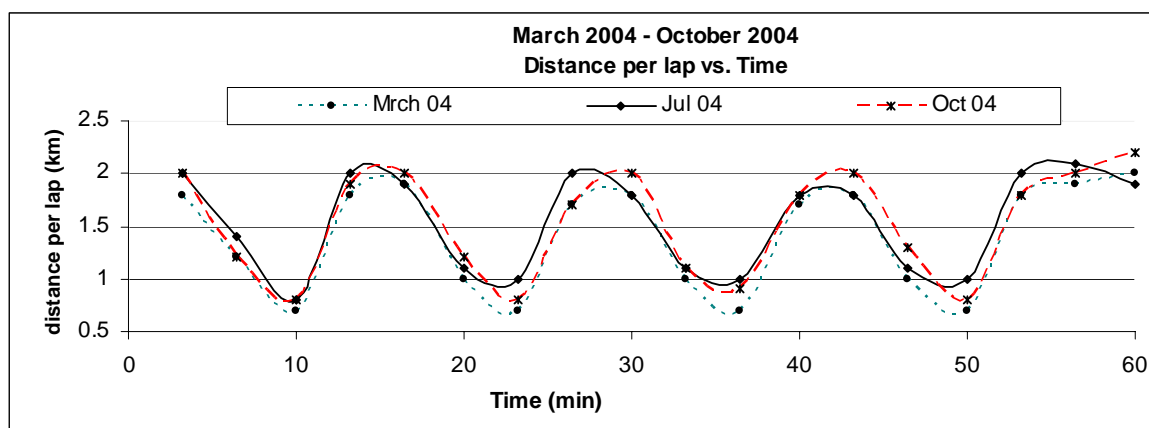
The results of this test are presented in Table 47

Table 47. Values obtained during 1-hour distance trial for CS2 (Third Macrocycle)

	March 2004	June 2004	July 2004	October 2004
Total distance (km)	25.2	DIDN'T DO THE TEST	28.12	27.4
Avg cadence (rpm)	74±14		86±14	81±10
Total distance 4% incline (km)	4.2		4.7	4.8
Avg cadence 4% incline (rpm)	70±6		76±2	75±5
Total distance 8% incline (km)	2.8		3.8	3.3
Avg cadence 8 % incline (rpm)	55±2		70±11	70±2
Avg heart rate (bpm)	150±8		177±13	175±10
Highest heart rate (bpm)	160		191	186

Total Distance. Graph 89 illustrates the split distance over time. For interpretation of the graphs, the reader is reminded that each lap represents 3 minutes and 20 seconds. To simplify the interpretation of the graph, it should be remembered that the first lap was a flat distance, the second a 4% gradient hill, the third lap an 8% gradient hill, followed by 2 flat laps, before the first 4 % gradient commenced again and the sequence was repeated four times. The last 10 minutes was flat. The peak distances were during the flat part of the test and the shorter distances during the climbs.

Graph 89. Lap distance (km) during 1-hour distance trial for CS2 (Third Macrocycle)

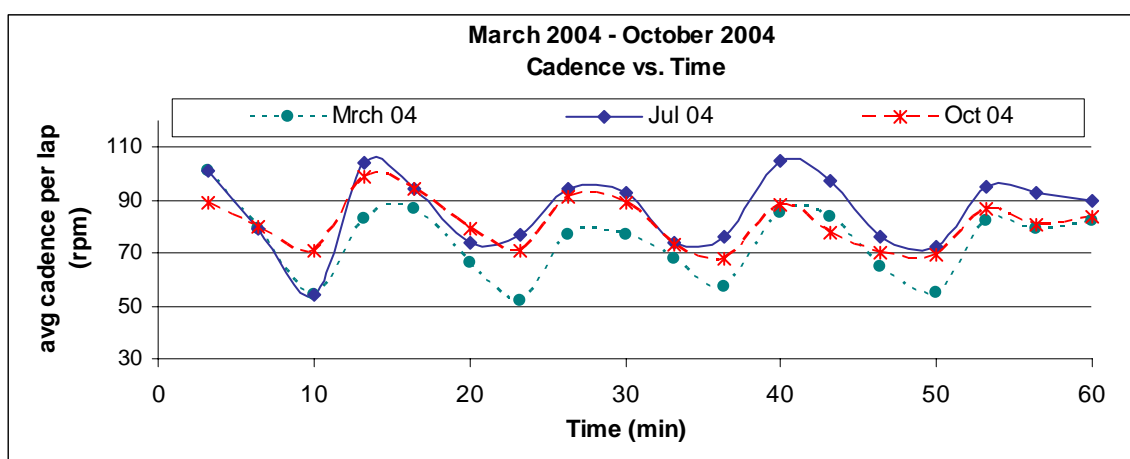


(Rationale for connecting the data points was presented in Chapter Three.)

- During July, the distance covered increased with 2.98 km. The increase in total distance was due a 1.48 km increase on the flat parts of the race, a 0.5 km increase on the 4 % gradient hill and a 1 km increase on the 8 % gradient hill.
- The total distance covered in October indicated a 0.72 km decrease from July, but was still much better than March. More specifically 0.5 km was lost on the 8 % hill.

Cadence (rpm). Graph 90 is an illustration of the cadence averaged per lap over the period of time. The cadence was higher on the flat part of the race and lower on the hills.

Graph 90. Cadence (rpm) selection during the 1-hour distance trial for CS2 (Third Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

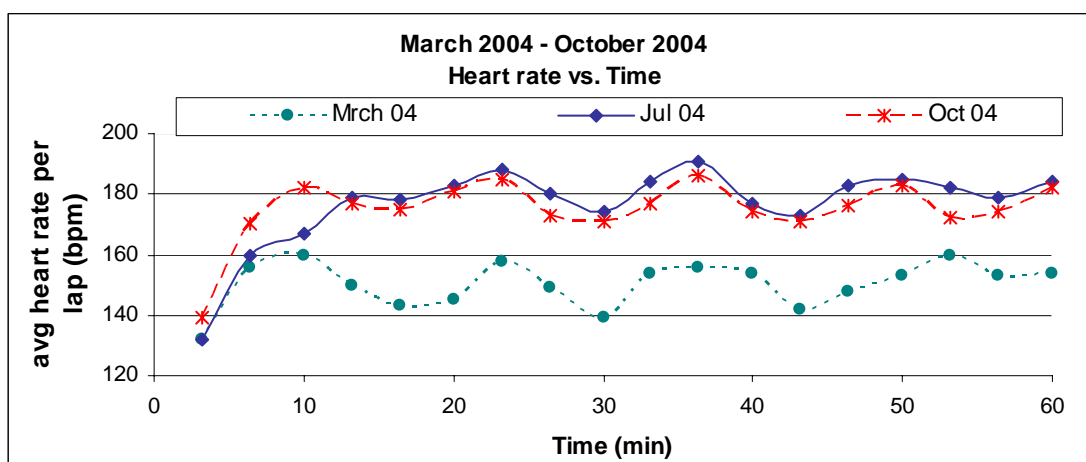
The graph above indicates that CS2 had variable cadence selection over all three test periods.

- During March, the average cadence during the 1-hour distance trial was 74 rpm and on the 4 % gradient hill, 70 rpm. The cadence selection of the 8 % gradient hill was 55 rpm.
- The average cadence for July improved to 86 rpm, with improvement to 76 and 70 rpm on the 4 % and 8 % hill, respectively. An increase in cadence of 12 rpm on the average cadence alone is visible. The increase on the 8 % gradient hill is 15 rpm.
- The average cadence for October was 81 rpm, with a cadence of 75 rpm on the 4 % gradient hill and 70 rpm on the 8 % gradient hill. The average cadence on the hills

was close to those used in July, therefore the decrease in overall average was relate to decreased cadence on the flats.

Heart Rate (bpm). Graph 91 illustrates the heart rate (bpm) averaged per lap over the time period of the test.

Graph 91. Heart rate (bpm) during 1-hour distance trial for CS2 (Third Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

CS2's maximum heart rate of 206 bpm from the incremental exercise tests in July and October, was taken as HR_{max} .

- In March, CS2 averaged at 72.8 % of HR_{max} and 84% of HR_{OBLA} achieved in March. His heart rate may have reflected a lack of motivation that might have played a role during this test.
- In July, CS2 average at 86 % of HR_{max} , and 102% of HR_{OBLA} achieved in July. His average heart rate was 9 bpm lower than in October, mainly because it rose steeply at the beginning of the test. Other than this, the October test was similar to the July test.

Summary of 1-hour Distance Trial. The best distance for the 1-hour distance trial was recorded in July, when the highest average heart rate as well as the highest average cadences were achieved. The distance CS2 covered on the 8 % hill indicates that he was better prepared to cycle at a higher cadence on the hills and could maintain the intensity as well to cover the greater distance. During July and October CS2 was able to cycle at an average HR above his HR_{OBLA} and higher than 85 % of HR_{max} .

1 km Time Trial

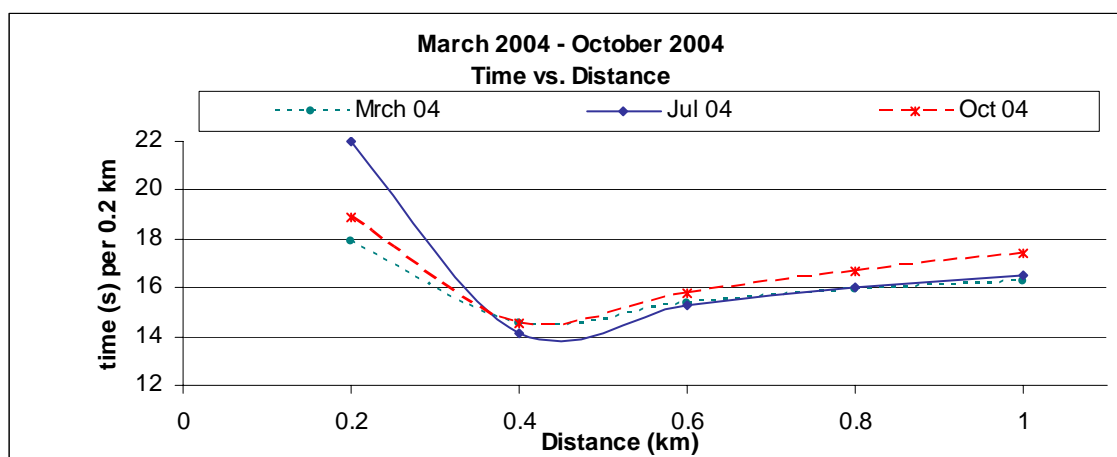
Results of the 1 km time trial are presented in Table 48.

Table 48. Results during the 1 km time trial for CS2 (Third Macrocycle)

	March 2004	June 2004	July 2004	October 2004
Gear selection	90	DIDN'T DO THE TEST	90	90
Time (min:s)	1:19.9		1:21.6	1:25
Avg cadence (rpm)	113±6		112±7	106±7
Avg speed (km/h)	45±3		44±7	42±4
Avg heart rate (bpm)	164±28		172±25	172±30
Highest heart rate (bpm)	180		187	192

Time / Distance. Graph 92 illustrates the time taken (s) for each 0.2 km over during the 1 km time trial.

Graph 92. Time taken (s) for each 0.2 km during the 1 km time trial for CS2 (Third Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

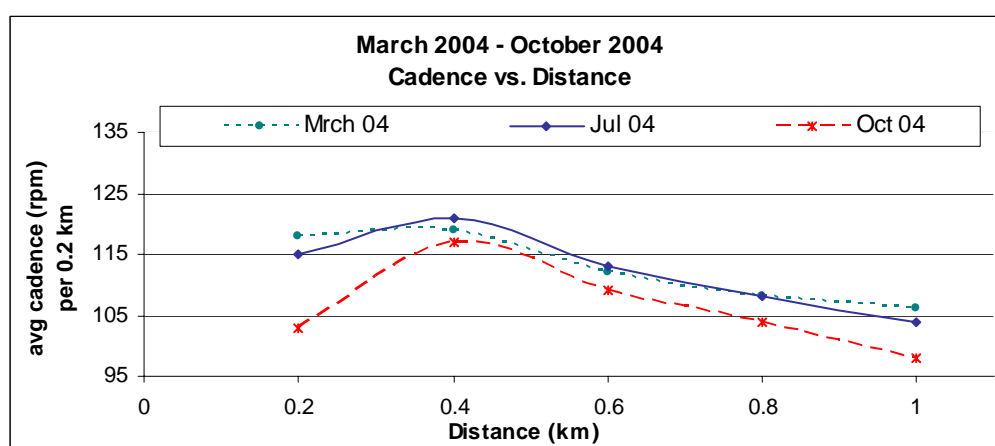
This graph is an indication of the 1 km track time trial capacity of CS2 and the tactics he used.

- In March, the start over the first 0.2 km was the fastest of the three tests, but he did not achieve maximal speed. Not only had he the fastest start, but his capacity to maintain the speed was also better than in October.
- July results revealed a slow start but the fastest maximum speed of 50.7 km/h achieved between 0.4 km and 0.6 km. He maintained his speed quite well after that.

- In October, he achieved a faster start than in July, but a little slower than March. His speed at the end of the race was the slowest of the three tests and this indicates a lack of muscular endurance and the capacity to maintain speed, although motivation might also have influenced the results.

Cadence (rpm). Graph 93 illustrates the cadence (rpm) averaged for each 0.2 km during the 1 km time trial.

Graph 93. Cadence (rpm) selection during 1 km time trial for CS2 (Third Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

Because no gear change is possible on a track bike, gear selection is important when considering the cadence used. During all three trials the gear selection was 90. Graphs of cadence therefore also will indirectly indicate the speed.

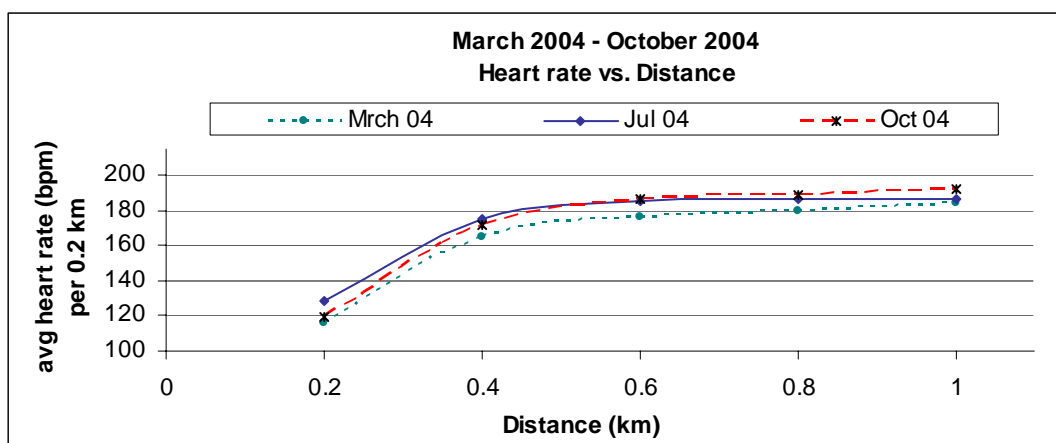
- March indicate the highest cadences for the first 0.2 km and a good capacity to maintain it. The maximum cadence achieved in March was 119 rpm, with the slowest 106 rpm. This indicated an 11 % decrease in cadence over the test.
- In July, the cadence over the first 0.4 km was also good, with a peak of 121 rpm achieved at 0.4 km. The slowest cadence of 104 rpm at the end indicated a 14 % drop in cadence. The average cadence of 112 rpm was only 1 rpm slower than in March, but resulted in a 1.7 sec difference in time.
- In October, CS2's peak sprint power and muscular endurance could not reach or maintain the cadences achieved before. A 16% drop in cadence is visible.

A small difference in cadence can result in a big time difference when it comes to competition. This is an indication of the importance of the capacity to maintain a good

cadence. Maximum cadence does not appear to be as important a factor as the capacity to maintain a fast cadence.

Heart Rate (bpm). Graph 94 illustrates the heart rate (bpm) average for each 0.2 km during the 1 km time trial.

Graph 94. Heart rate (bpm) during 1 km time trial for CS2 (Third Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

- During March an average heart rate of 164 bpm and a highest heart rate of 180 bpm were achieved despite best performance.
- The July and October average heart rate was both 172 bpm, with a highest heart rate of 192 bpm in October despite the worst performance, indicating fatigue rather than a lack of motivation.

Summary of 1 km Time Trial. March results indicated the fastest time, with the slowest in October, although October results indicate together with July results the highest average heart rate. This can indicate either detraining after competition or peaking too early before competition.

3 km Time Trial

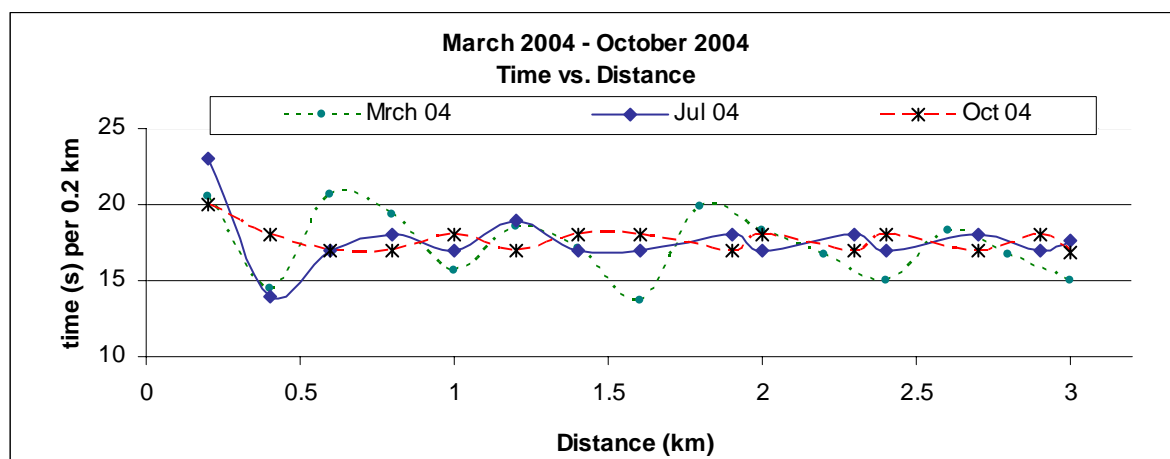
Results of the 3 km time trial are presented in Table 49.

Table 49. Results during the 3 km time trial for CS2 (Third Macrocycle)

	March 2004	July 2004	October 2004
Gear selection	90	90	90
Time (min:s)	4:19.9	4:24.6	4:24.8
Avg cadence (rpm)	102±4	101±2	101±1
Avg speed (km/h)	42.9±2	41.9±1	42.1±2
Avg heart rate (bpm)	172±21	181±16	183±18
Highest heart rate (bpm)	187	194	191

Time / Distance. Graph 95 illustrates the time taken (s) for each 0.2 km during the 3 km time trial.

Graph 95. Time taken (s) for each 0.2 km during the 3 km time trial for CS2 (Third Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

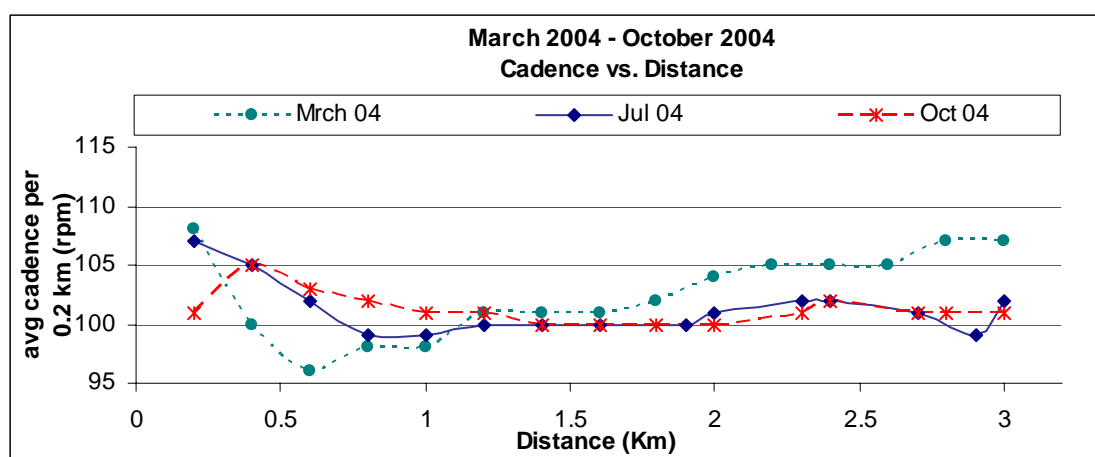
This graph is an indication of the riding capacity during the 3 km track pursuit as well as the tactics used during the test.

- During March, a great variability is visible. The average speed of 42.9 km/h was the fastest of the three tests.
- July results revealed a slow start over the first 0.2 km, but the fastest time of the three between 0.2 km and 0.4 km. This simulated the pattern of the 1 km time trial. The speed throughout the test stayed constant with an average speed of 42.1 km/h, indicating more constant pacing, although this not translate into better performance.

- October indicated a start similar to those of March, but never achieved the same maximum speed. The speed was constant throughout the test at an average of 41.9 km/h.

Cadence (rpm). Graph 96 illustrates the cadence (rpm) averaged for each 0.2 km during the 1 km time trial.

Graph 96. Cadence (rpm) selection during 3 km time trial for CS2 (Third Macrocycle)



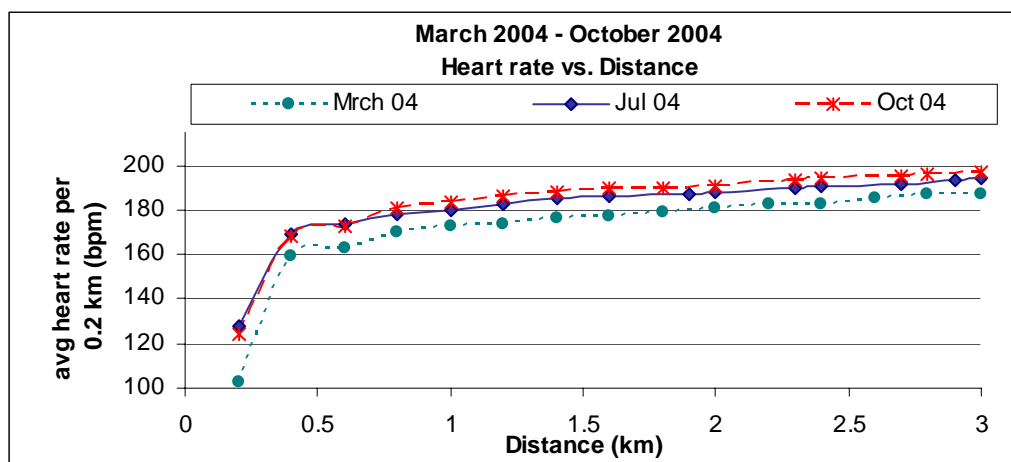
(Rationale for connecting the data points was presented in Chapter Three.)

The fact that no gear change is possible on a track bike, means that gear selection is important when considering the cadence used. The gear selection was 90 for all three tests.

- March indicated a high starting cadence of the first 0.2 km but a decrease in cadence to the lowest cadence between 0.4 km and 0.6 km (96 rpm). The gradual pick-up in cadence over the next 2.4 km to the end resulted in an average cadence of 102 rpm during the test.
- A similar average cadence of 101 rpm was achieved in July, but with a different strategy. A maximum cadence of 107 rpm was achieved in the first 0.2 km, with a more gradual decrease in cadence towards the 1 km mark with the slowest cadence of 99 rpm. After the 1 km mark, the cadence was constant with no real final burst.
- October indicated a different tactic with the maximum cadence of 105 rpm achieved only during 0.2 km and 0.4 km, thus starting out slower. A small decrease in cadence is visible towards the end of the race, but it never dropped below 100 rpm. Performance was the same as in July.

Heart Rate (bpm). Graph 97 illustrates the heart rate (bpm) average for each 0.2 km over the distance (km) covered.

Graph 97. Heart rate (bpm) during 3 km time trial for CS2 (Third Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

- During October the highest average heart rate was recorded whereas heart rate was lowest during the March trial. Therefore, the fastest 3 km time trial had the lowest average heart rate. This indicates cardiovascular adaptation to training had occurred, before the March trial.

Summary of 3 km Time Trial. The 3 km time trial of March was the fastest with an average cadence of 102 rpm. The pacing was not constant throughout the test and that is a factor CS2 can look at improving. It is interesting to note the difference in tactics for the October 3 km time trial. The slower start might be due to a lack of peak sprint power or due to a decision to start of slower.

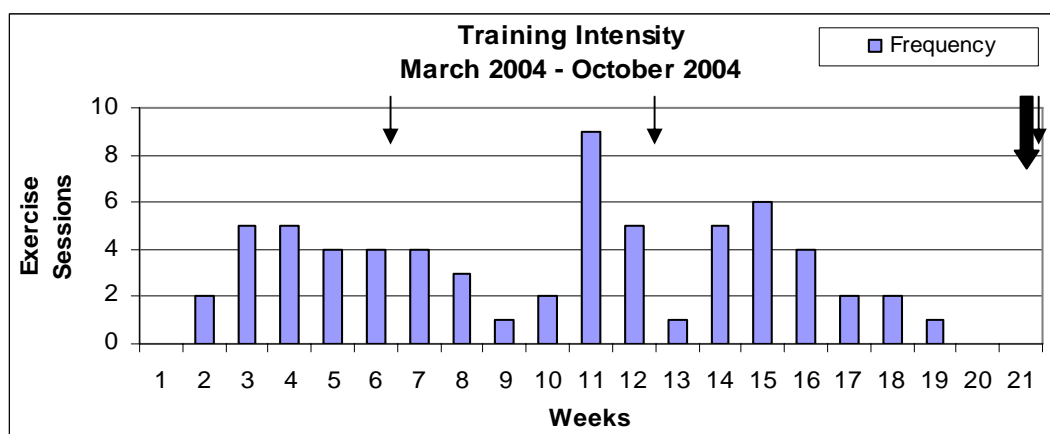
Training

Heart rate monitor data as well as CS2's training logs were used to determine the training intensity, volume, frequency and the mode of training during this macrocycle.

Training Frequency

Graph 98 illustrates the exercise sessions per week for the Third Macrocycle.

Graph 98. Training frequency for CS2 (Third Macrocycle)



Indicative of the competition times.



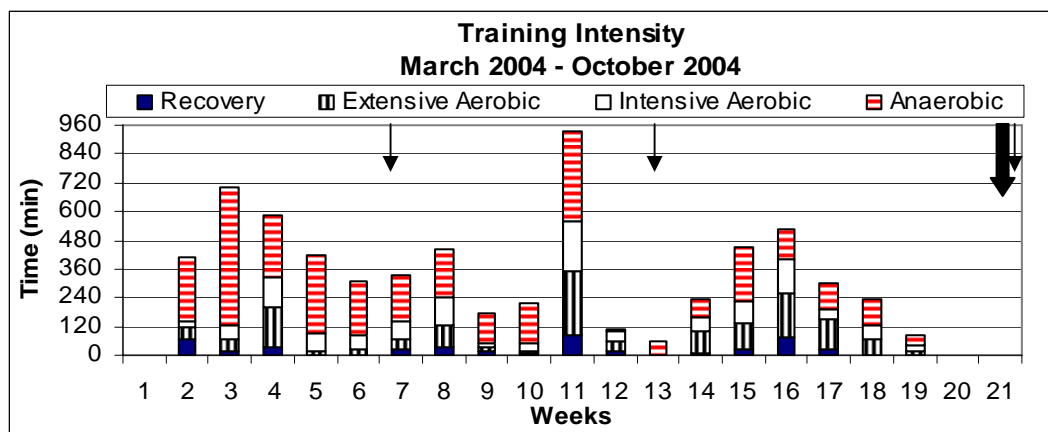
Indicative of testing times.

A constant training frequency during weeks 1 – 6 (average 3 sessions per week) is visible. Weeks 8, 9 and 10 showed a decrease in training frequency. This was in CS2's exam time. Week 11 was the peak training week during the Paralympic Residential camp where CS2 trained eight sessions for the week. Week 13 indicated a drop in training, but it excluded the testing times during that week. Weeks 13 -18, which were in the pre-competition phase, indicated good training frequency during weeks 14 – 16 , with a drop to an average of 2 sessions for the three weeks before the Paralympic Games ()which may be a rather sudden taper.

Training Intensity

Graph 99 is an illustration of the average heart rate training intensities during each week.

Graph 99. Training intensity for CS 3 (Third Macrocycle)



↓ Indicative of the competition times. ↓ Indicative of testing times.

Table 50. Percentage of training time in each training zone for CS2 (Third Macrocycle)

Weeks	Recovery Zone (<70%)	Extensive Endurance (70-80%)	Intensive Endurance (80-85%)	Anaerobic (>85%)
1- 6	4.7 % (114min)	12.8 % (310 min)	14.2% (343 min)	68.3 % (1649 min)
7-12	8.6 % (181 min)	22.5 % (474 min)	22.8 % (480 min)	50.9 % (1070 min)
13-18	7.6 % (137 min)	31.9 % (547 min)	21.6 % (388 min)	38.9 % (701 min)
19-20	Data not fully captured during this 3 weeks of training.			

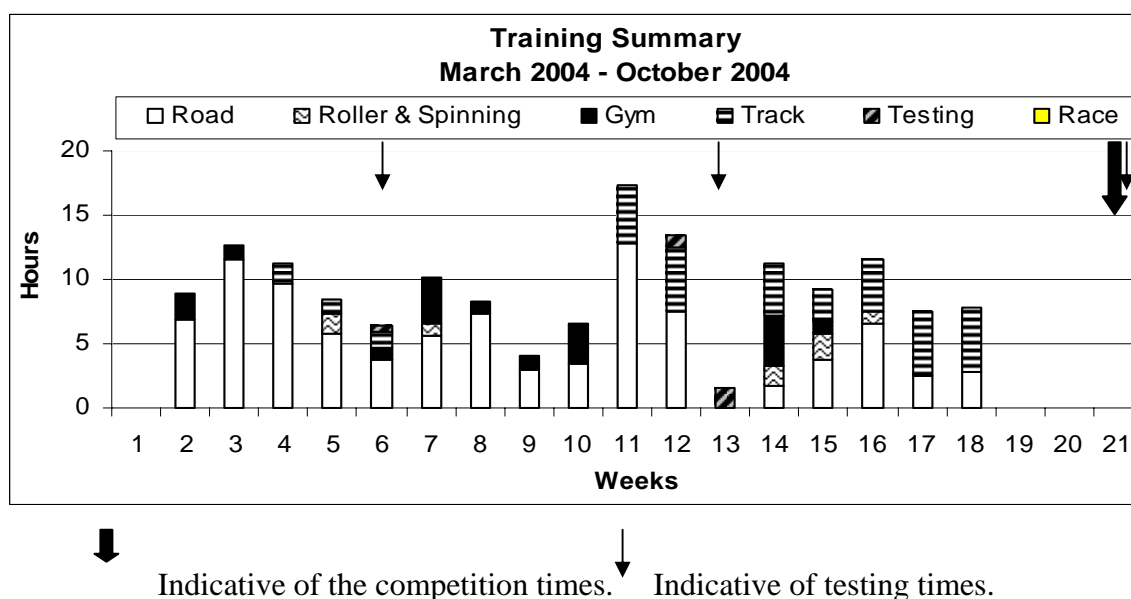
It is important to note that during weeks 19 -21, not all the training data were collected and therefore not reported on the graph. Data gathered for this graph was only heart rate data (Polar Accurex Plus). During the first six weeks of the Third Macrocycle, training was supposed to focus on long sustained rides to build a base for future high intensity training. On average, CS2 trained 6.7 hrs per week during the first 6 weeks. Of his training during this time, 82.5 % was above 80 % of maximal heart rate. This indicates high intensity training. His training therefore did not incorporate the lower heart rate intensity training that was recommended to take place during this phase.

During weeks 7 -12 he had a 9 % decrease in training time. Part of this decrease is due to exams taking place during this time period. This time period also includes the training at the Paralympic Camp in Weeks 11 and 12. He spent 73.7 % of his training time in Weeks 7-12 above 80 % of HR_{max} . Weeks 13 – 18 is the pre-competition phase. It recommended in this phase to increase training intensity and decrease the volume of training, but his training volume decreased to 4.9 hrs per training week, with 60.5 % of his training above 80 % of HR_{max} . His training volume decreased with 17.7 % and the percentage of time spent above 80% of HR_{max} also decreased with 13.7%. No periodised training with systematic increase in training volume and intensity with subsequent recovery was evident. The maximum training time per week was achieved in Week 11, when slightly less than 16 hrs of training were reported.

Training Volume and Training Modes

CS2 noted the different training modes he used to do his training in his training logs. Training volume (km) was impossible to determine given that he used so many different modes of training, many of which could not be quantified in km. Hence the volume of training is expressed as duration (hours/week). Training volume was determined using the training logs and heart rate monitors data. Graph 100 illustrates the different training modalities used during the Third Macrocycle.

Graph 100. Training summary for CS2 (Third Macrocycle)



During the first 6 weeks, CS2 spend 80 % of his training time on the road and 8 % of his training on the track. The rest of the training was done either in the gymnasium or on

roller training. Weeks 7 -12 shows a decrease in percentage time spent on the road to 67%, but and increase percentage time spent on the track (16 %). This is indicative that the training became more specific. During weeks 13 -18 when training should become very specific, his training did show a decrease in percentage time spent on the road (35 %) and an increase in time spent on the track (42 %). The decrease in time spent on the road could have been detrimental for his aerobic capacity, but the increase in track training provided the high intensity training that is important for track racing..

General Summary of Training

During the Third Macrocycle, the main focus was training to compete at his best at the Paralympic Games. CS2's periodisation was not as systematic as it should have been. During weeks 1 - 6 it was important to train at lower intensities. During weeks 7 -12, an increase in training volume and intensity should have occur and instead the training volume decreased. During weeks 13 – 18, the volume should have started to drop and the intensity should have increased. The amount of time spent doing track racing indicates where CS2's main focus was, but he should have spent more time on the road as well.

Direct Factors Targeted during the Third Macrocycle

The research question guiding this study focused on the management of selected direct factors important for sport performance management. The following rating scale reflects the investigator's perceptions of the degree of success in managing these factors.

Direct Factor	Score	Reasons
Performance Assessment	4	The main goal was to compete at his best at the Paralympic Games. CS2 felt that he could have achieved better especially in the track events. He felt very nervous. The laboratory assessment after the July testing might not have been accurate due to the heavy amount of training done the two weeks before assessment. Motivation as well as detraining might have had an influence on CS2's results during the October testing.
Periodised Planning of Training	2	Volume of training increased, but his intensity needs a lot of work. Lack of competition training before the main competition is also a factor that needs to be considered.
Feedback of Training	3	Needs to improve the feedback of training especially during competition preparation.
Training Sessions	3	A lot of training was done in the anaerobic zone. His modes of training were good, but he could have spent more time on the road during weeks 13 – 18.
Training Camp	4	The Paralympic training camp was positive. Not only did CS2 train more hours, but also at a lower heart rate intensity when conducting the longer rides. He therefore had a more balanced training while maintaining a relatively high amount of time in the anaerobic zone.
Sports Medicine Services & Products	5	Full service available. Full medical, nutritional, psychological and vision assessment completed at first training camp in May, 2005 by the team professionals. Feedback was given to CS2 by them. Due to confidentiality, no feedback was given to the investigator. During the training camp in July, two massage sessions per week were given to CS2, as well as two aqua-recovery sessions. CS2 went for massages for biweekly massages after the training camp until the Paralympic Games. CS2 received a new road bicycle as well as competition wheels for the track race. He continued to go for massages at least once every two weeks.

Score = Point out of 5, with 0 not achieved, 5 fully achieved.

Summary of the Management of Selected Direct Factors for CS2

The research question guiding this study focused on the management of selected direct factors important for sport performance management. The following is a discussion of the selected direct factors, the outcomes as well as the circumstance that could have influenced the outcomes.

Performance Assessment

Competitions

CS2 was able to compete in all the major competitions available for him. He did compete in the European Championships after the injury, and that was an important goal. The second goal was to make the Paralympic Team, and that was achieved as well. In Athens, his goal was personal best performances in the track racing and to be competitive in the other two events. He did not perform up to his potential during the first track race at Paralympic Games. His belief that he is a better track cyclist than road cyclist, definitely hinders his performance on the road.

Physiological Monitoring

Anthropometry. The data indicated that CS2 had a fat percentage of 8 % during the Paralympic competition, with the range 8- 9.6% over the three macrocycles. According to Winnick & Short (1995), his cerebral palsy should not influence his skinfold measurements and a 0.2 % variance in percentage fat can be attributed to day to day variance (Jackson et al., 1988). CS2's average body mass at competition time was quite constant. His natural growth as well as gymnasium work increased his body mass from a 70.95 kg in March, 2003 to 76.6 kg in October 2003. After his body mass increase in October, 2003 to 76.6kg, it stayed constant. His average BMI (body mass index) at competition time is 23.6 kg/m². Comparing this to the anthropometric characteristics of an able-bodied cyclist, his average fat percentage was within the range of 8 -10 %, and his BMI was higher than that of a time trial specialist (22 kg/m²) (Lucia et al., 2001), as well as that expected from a climber (19-20 kg/m²). It will therefore be beneficial for CS2 to have a competition body mass of 72 -73 kg, which could only be achieved with less upper body muscle mass together with some loss of body fat.

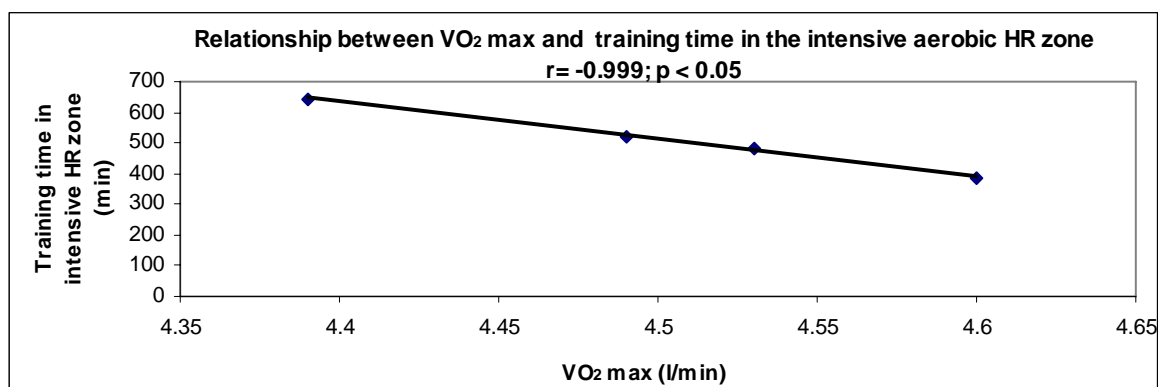
Incremental Exercise Test to Exhaustion: Pedaling Efficiency. Oxygen uptake at a given sub-maximal workload for children with cerebral palsy has been found to be equal to their able-bodied peers (Rose et al., 1993), but that oxygen cost is higher for persons with cerebral palsy (Bowen et al., 1999; Unnithan et al., 1996).

The peak value achieved for PPO was in June 2004 with 333 Watts, but the peak value for VO_2max (4.6 l/min) was achieved in October 2004. A 16 % increase in Watts from start to maximum value (June, 2004) is documented for CS2. The VO_2max shows less than 1 % increase. Literature indicates PPO as an important contributor to performance (Coyle et al., 1991). However it should be noted that CS2 has subsequent to this study been diagnosed with exercise induced asthma which could explain the fluctuations in VO_2max at high workloads during the incremental tests.

In a summary by Mujika & Padilla (2002) cyclists are classified according to training and racing status. CS2 falls into the well-trained category that shows values for PPO/kg between 5.0 - 6.0 W/kg and VO_2max values between 5.0 - 5.3 l/min. CS2's maximum values for VO_2max was 13 % lower (5.3 l/min) and the PPO/kg value 27 % lower (6 W/kg), than recommended for well-trained able body cyclists.

The Investigator calculated correlation coefficients (Pearsons product moment) between the different laboratory tests and the total as well as percentage of training time spent in each zone. Various good correlations has been found but they were not statistically significant ($p > 0.1$) correlations because of the small number of data points ($n=4$). VO_2max had a negative correlation ($r=-0.99$) with time spent in the intensive training zone (80-85% of HR_{max}) (see graph 101). This indicates that the more time CS2 spent in the intensive zone, the lower his PPO and VO_2max . This can be either due to less time spent in the other zones or that time spent in the intensive zone might be detrimental to aerobic endurance capacity. Training to improve VO_2max and PPO consists of sustained training at high intensity (Gregor & Conconi, 2000; Friel, 2003 & Janssen, 2001). It is therefore interesting to note that for CS2 that training at 80-85% of HR_{max} had negative correlations with VO_2max . The assumption is that he spent too much time in this zone and too little time in the extensive endurance zone. His training in the intensive zone might not have been specific enough to generate the adaptations to improve PPO and VO_2max .

Graph 101: Relationship between VO₂max and training time spent in the intensive aerobic zone.



The incremental tests to exhaustion from October, 2003 – October, 2004 (6 tests), were conducted on the LODE ergometer, able to determine the power output of the left and right leg separately as well as the range of power output across each revolution of the pedal.

Table 51 is a summary of the average data of the six different test sessions.

Table 51. Summary of the pedal force measurements during incremental tests to exhaustion for CS2

	210 W	240W	260W	280W	300W	320W
Avg RPM	107±3.9	109±1.7	108.2±3.7	105.5±5.1	101.8±3.7	92±6.3
Avg Watts Left	146.4±2.9	161.8±3.7	170.8±5.5	182.7±4.4	192±6.8	202.5±4.9
Avg Watts Right	81.7±2.8	96±6.4	106±6.1	115.2±5.7	124±54.8	131.2±3.7
Avg Max Watts Left	577.2±18.1	660.7±22.9	708.8±23.4	769.3±32.1	798.5±54.9	747.2±46
Avg Max Watts Right	398±17.4	453.3±27.6	485.5±22.4	516±19.4	530.8±21.3	536.7±12.2
Avg Min Watts Left	-116.5±9.5	-122.8±20.1	-114.7±31.4	-107.7±20.9	-98.2±21.2	-76±17.5
Avg Min Watts Right	-155±17.5	-148.8±14.2	-141.7±19.3	-128.5±14.2	-123.8±17.3	-96.3±17.4
Efficiency	80.8±1.3	82.8±1.6	84.8±2.3	86.7±1.9	88.5±2.2	92.1±1.5
Ratio L	64.3±1.3	62.7±1.5	61.7±1.6	61.3±1.2	60.9±1	60.8±0.6
Ratio R	35.6±1.5	37.3±1.5	38.3±1.6	38.8±1.3	39.1±1	39.3±0.6

- **Average RPM.**

The average rpm was calculated as the average number of revolutions per minute at each workload over the six test sessions. CS2 was able to cycle at an rpm over 100 for the first 5 workloads and only at the last workload did his rpm drop below 100. His ability to cycle at such high cadence might be due to the amount of track training he did where he needed to cycle at a fast cadence.

- **Efficiency.**

An efficiency of 100 is seen as a perfect cycling action with no resistance applied against the cycling action. Resistance is applied during the upstroke by the weight of the lower limb which has to move or be moved against gravity. Resistance can be relieved in two ways: 1) actively by “pulling” the pedal up (hamstring action of the same limb), or 2) passively by the force of the downward stroke of the opposite leg. A negative value for the average minimum Watts per leg, indicates that forces were applied against the pedaling action.

It is interesting to note that the easier the workload, the more negative force was applied by CS2 to the pedals. His left and right leg were responsible for negative values against the cycling action, with the right side producing $\pm 20\%$ more negative resistance than the left side (CS2's right side is the hemiplegic side). The high cycling cadence with little resistance may result in a problem with muscle coordination, especially when taking cerebral palsy into consideration (Parker et al., 1992). His efficiency improved from 80.8 % with about 2 % at each workload. CS2 had an efficiency of 92.1% at the last workload of 320 Watts. Kaplan (1995) studied cycling patterns for persons with cerebral palsy and found that although they push down and pull-up faster in the cycling action, there is a delayed transition time between push and pull. This might be the reason for the increased negative resistance of CS2 in this study.

- **Left - Right Leg Ratio.**

This ratio is an indication of the percentage of the total Watts each leg produced during each workload. The goal is to achieve a 50:50 ratio between the two legs. During the easy workloads, the ratio between the two legs was 64: 39, left to right leg. This ratio improved as the workload increased and the best ratio achieved was

during the last workload of 320 Watts, where a ratio of 61:39 (left to right) was achieved. This improved ratio was due not only to improved power output by the right leg (see increase in max watts), but also to a decrease in the resistance applied by the right leg (see decrease in negative minimum watts), against the down stroke force of the left leg. Parker et al. (1992) stated that persons with cerebral palsy find it difficult to produce power at a high speed, which supports this fact. CS2 was more efficient at higher workloads due to the lower cadence and more time to produce the power necessary.

Incremental Exercise Test to Exhaustion: Heart Rate Efficiency. Maximal heart rate used during the macrocycles was 206 bpm. The maximal heart rate achieved in the incremental exercise tests to exhaustion varies between 198-206 bpm. Of importance is that at sub-maximal levels, the goal was to cycle at lower heart rates. The best heart rate efficiency during the three macrocycles was at competition time.

Incremental Exercise Test to Exhaustion: Fuel Utilization. The longer a cyclist can ride under a RER of 1, the better his/her capacity to use oxygen to burn fat to produce energy for the cycling action. This results in sparing the glycogen stores for higher intensity work later in the race, when needed. CS2 showed a limited capacity to utilize his fat oxidative energy system and even to fully oxidize carbohydrates. During the First Macrocycle, he was able to start the test at a RER lower than 1 only in October. This improved as the study progressed. During June and July, 2004, his capacity to utilize his oxidative system was adapted the best with a RER of 1 reached at 280 and 260 Watts respectively. This was at 84 % and 79 % of PPO. During March, 2003, the Watts at RER of 1, was at the start of the test at 210 Watts and during June, 2004, the Watts at RER of 1 was 280 Watts. This is a 33 % improvement. The heart rate at RER of 1 varied between 150 – 182 bpm.

Incremental Exercise Test to Exhaustion: Lactate Accumulation. A lactate of 2 mmol/L was seen in CS2 consistently at rest. Since this was also seen a few times in CS1 it would appear that this observation is due to CP. Watts at OBLA for professional cyclists are around 87 % of maximal Watts (Mujika & Padilla, 2001). CS2's best Watts at OBLA was in June, 2004, at 75 % of PPO. Persons with cerebral palsy present with higher lactate concentrations than their able-bodied peers at sub-maximal workloads (ACSM, 1997). CS2's limited training time in the extensive endurance zone (70-80% of HR_{max}), may have had an effect on this factor. During Macrocycle One, HR_{OBLA} varied between 184-187 bpm, which

presented approximately 90 % of HR_{max} . During the Second and Third Macrocycles, this decreased to vary between 171-179 bpm (83-87 % of HR_{max}). Mujika & Padilla (2001) stated that for time trials shorter than 30 minutes, HR_{OBLA} is a good indicator of HR to be achieved during these time trials.

CS2's capacity to cycle at high lactate values was indicated by the improved maximal lactate values achieved after the last workload. In April, 2003, the maximal lactate value was 11.4 mmol/l, and in July 2004 this improved to a maximum of 18.5 mmol/l.

Wingate Test. The Wingate 30 second anaerobic test was found to be a valid test to evaluate peak sprint power and anaerobic capacity for persons with cerebral palsy (Parker et al., 1992; Tirosh et al., 1990). Cyclists with cerebral palsy find it difficult to produce power at high speed (Parker et al., 1992). Peak mean and sprint power for CS2 was found in July 2003, after limited training. CS2 was injured and did a lot of one leg hopping on the non-cerebral palsied leg as means of transport. This incidental power training might have resulted in increased power in the legs to produce the highest peak sprint power of the study period. Alternatively, the number of core stabilization exercise sessions during rehabilitation may have contributed to his improved ability to have a better pedaling motion. If one excludes the test results of July, 2003, his peak sprint power in Watts showed an 8 % improvement from March 2003 – October 2004, and his mean sprint power a 7 % improvement. When body mass was taken into consideration, the improvement for peak sprint power was only 1.5 % and for mean sprint power, less than 1 %. The fact that peak sprint power and mean sprint power are mainly indicative of track performance where Watts are more important than Watts/kg, his improvement is regarded as important.

No significant ($p < 0.05$) correlations were found between training and peak and mean sprint power, or between peak and mean sprint power and the simulated track time trials.

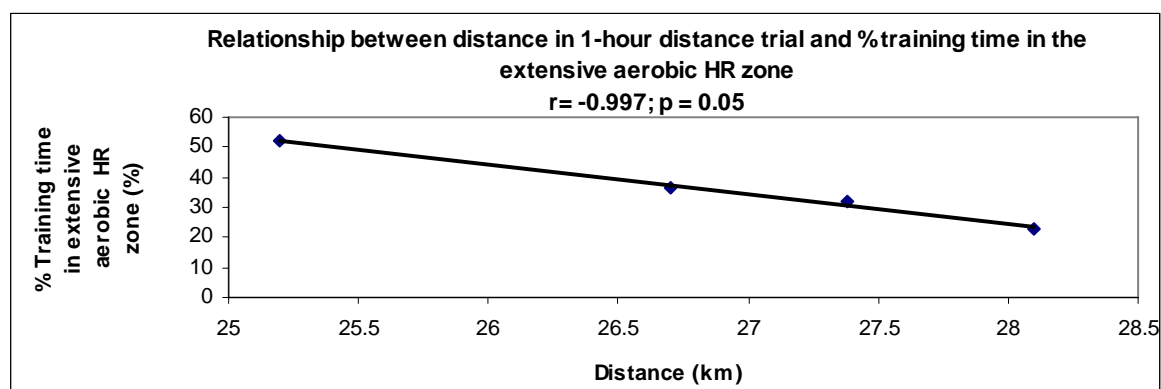
1-Hour Distance Trial. The 1-hour distance trial performances fluctuated a great deal. The distance covered by CS2 in the 1-hour distance trial improved from 24.4 km to 28.1 km (July 2004). This is a 15 % improvement. CS2's average cadence on the 1-hour distance trial varied between 74 rpm and 94 rpm. CS2 showed in some of the tests that he did have the ability to cycle above 70 rpm on the hills, but never achieved the 84 rpm found by Swain and Wilcox (1992) to be the most economical. CS2 needs to work on improving his cadence cycling uphill. This is especially important outdoors considering his high body mass.

The average heart rate achieved during all of the 1-hour distance trials was above 85% of HR_{max} , except in March 2004 when CS2 was only able to cycle at 73 % of HR_{max} . A study by Padilla et al. (2000) found that in professional road cycling, during a tour the cyclists are able to cycle at 80 ± 5 % of their HR_{max} during the long time trials and 85 ± 5 % of their HR_{max} during shorter time trials. During uphill time trials, the professional cyclists were only able to achieve 78 % of their HR_{max} . CS2 therefore showed he had the capacity to cycle at a high percentage of his HR_{max} during the 1-hour distance trials. He was able to ride at 95 - 103 % of his HR_{OBLA} during all 1-hour distance trials except the March trial, when he cycled only at 84 % of HR_{OBLA} . Pacing strategy assessed from power output in varying external conditions is found to be useful, but the use of heart rate has been questioned (Atkinson & Brunskill, 2000). It is interesting to note that a constant pacing at constant external conditions has been found to be optimal, but with varying external conditions like hills or winds, it is more optimal to adapt power to the conditions (Atkinson & Brunskill, 2000).

No statistically significant ($p < 0.05$) was found when considering the 1-hour distance trial average heart rate and training (limited data points, $n=4$). However, a negative correlation ($r = -0.93$, $p > 0.05$) between total training time and average heart rate in 1-hour distance trial was found. A higher negative correlation ($r = -0.95$, $p > 0.05$) between percentage training time in the extensive endurance zone was found. Although not significant, these results may indicate that the more training as well as more training in the extensive endurance zone, can result in a lower average heart rate on the 1-hour distance trial. This in its turn can either mean that either CS2 was unable to cycle at higher intensities or that he could use a lower heart rate intensity to achieve the same distance.

The distance cover in the 1-hour distance trial correlates also negatively ($r = -0.99$) with percentage time spent in the extensive endurance zone. Graph 102 illustrates this relationship.

Graph 102: Relationship between 1-hour distance trial distance and % training time spent in extensive endurance zone.



1 km Time Trial. The best time trial was during January, 2004 with a time of 1:17.2. He used an 88 gear and an average cadence of 119 rpm was achieved. Average cadence (gear not taken into consideration) indicate a trend to correlate significantly ($r=0.95$, $p < 0.01$) with speed achieved in the 1 km time trial (see graph 103). The average cadence in a 1 km time trial at able body World Championships has found to be 127 rpm. The question is: would the increase cycling cadence be detrimental for the cerebral palsy cyclist due to increased lack of coordination (Parker et al, 1992)? The positive correlation between cadence and speed might suggest that up to a certain cadence for CS2 his coordination does not affect his performance, since the 119 rpm resulted in his best time.

The average cadence achieved during the 1 km time trial, correlated significantly with the average cadence achieved over the first 0.2 km ($r=0.86$, $p < 0.05$) and 0.2 km -0.4 km ($r=0.83$, $p < 0.05$). If taken all into consideration a bigger gear will result in a slower cadence over the first 0.2 km and 0.4 km, except if peak sprint power increased. This slower cadence affects the average cadence that will result in a slower time. It was concluded that this factor requires more research.

3 km Time Trial

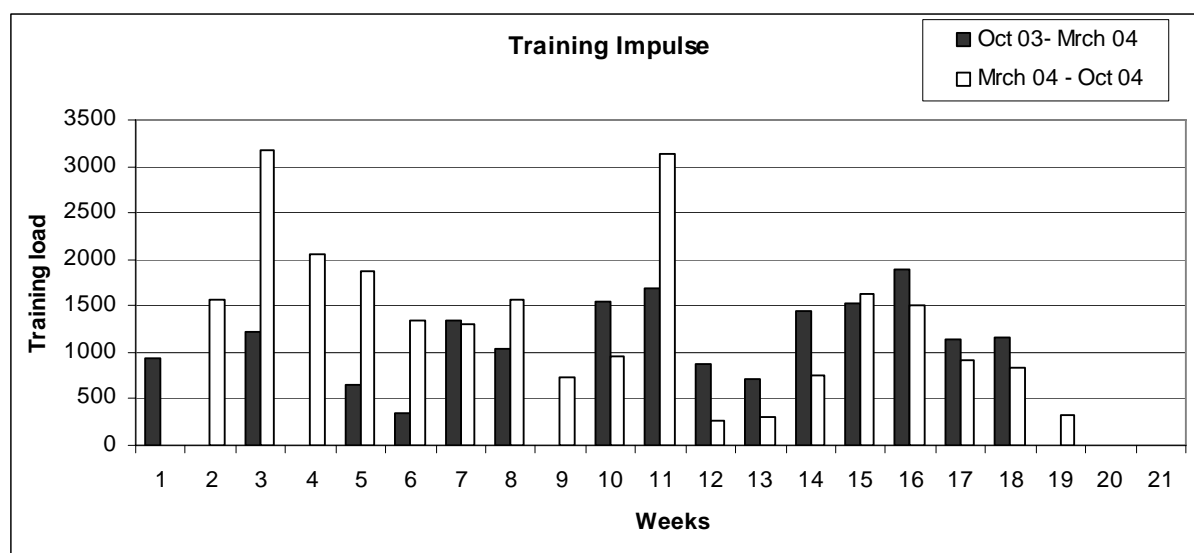
The best 3 km time trial was during January, 2004 with a time of 4:06.6. CS2 used an 88 gear and an average cadence of 111 rpm was achieved. Average cadence (gear not taken into consideration) correlated significantly ($r=0.91$, $p < 0.05$) with speed achieved in the 3 km time trial (see graph 104). The average cadence achieved during the 3 km time trial, correlated significantly ($r = 0.84$, $p < 0.05$) with the average cadence achieved over 0.2 km - 0.4 km. Pacing during the 3 km time trials varied quite a bit. More experimentation with different pacing strategies is recommended.

Periodised Planning of Training

An interesting indicator of training load is “training impulse” (Esteve-Lanao et al, 2005; Foster et al, 2001, Lucia et al, 2003; Mujika et al, 1996). Training impulse is calculated by multiplying the training time in each zone with the fixed factor allocated to that training zone. The total of the training impulse for each training zone is therefore the total training impulse.

Graph 103 is an illustration of the comparison between the training impulses for each week in Macrocycles Two and Three.

Graph 103. Training impulse for Macrocycle Two and Three for CS2



Graph 103 presents a comparison between the periodisation of the Second and Third Macrocycles. The training load indicated that the maximum training load achieved by CS2 in the Second and Third Macrocycle was 1897 and 3169 respectively.

Table 52. Breakdown of training loads per meso-cycle for Macrocycle Two and Three for CS2

Meso-cycles	Macrocycle Two		Macrocycle Three	
	Load	% Of Total Training in Mesocycle	Load	% Of Total Training in Mesocycle
Weeks 1-6	3150	18	10008	41.2701
Weeks 7-12	6498	37	7954	32.8
Weeks 13-18	7898	45	5954	24.55258
Weeks 19-21	TRAINING DATA NOT COMPLETE, THEREFORE NOT USED			
Total Training Load	17 546		24 250	

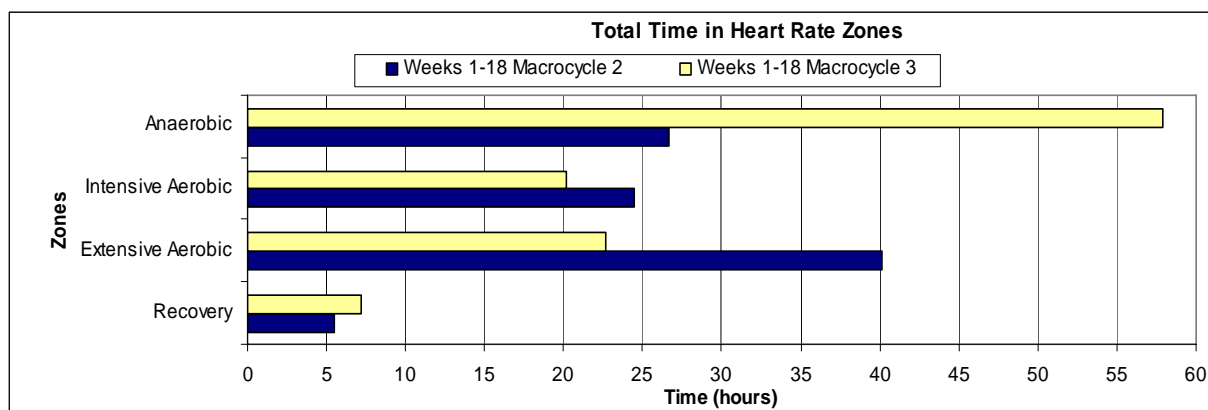
There was a 38 % increase in total training load between Macrocycles Two and Three, Weeks 1 -18. The spread of training load through the mesocycles did differ. The initial mesocycle in each macrocycle indicated a 69 % increase in training load from the Second to Third Macrocycle. During the Second Mesocycle in each macrocycle, the difference was less pronounced with the higher load (18 % more) in the Third Macrocycle. In the third mesocycle in each macrocycle, there was a 25 % difference, with the Second Macrocycle reflecting a greater training load. It is important to note that the data for the fourth mesocycle in the Second and Third Macrocycles was not complete due to CS2's preference not to wear the heart rate monitor during competition time or training close to competition.

The training load indicated that CS2 is capable of training at higher training loads than he did in the Second Macrocycle. The planning of his training can improve, with the highest training load achieved during the Second Mesocycle (weeks 7 -1 2) when high volume and intensity work should be done.

Time Spent in Each Training Zone

Periodization of a yearly plan incorporates the different intensities used to train. Graph 103 is an illustration of the time spent in each heart rate zone during Macrocycle Two and Three.

Graph 103. Training time spent in each heart rate zone for CS2 (2nd and 3rd Macrocycle).

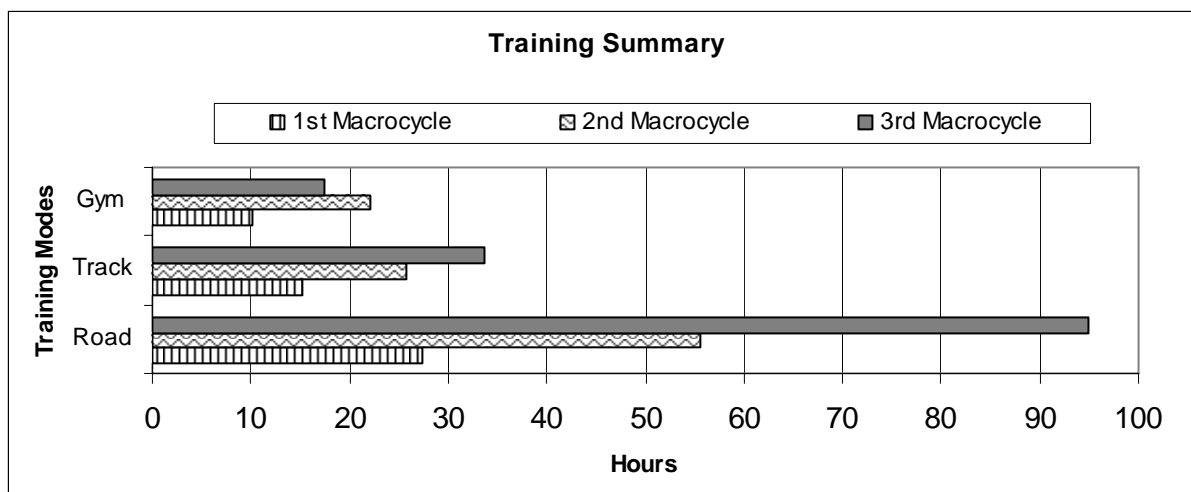


It is interesting to note in Graph 104 that during the Third Macrocycle, CS2 spent more time training in the anaerobic zone than he did during the Second Macrocycle, with greater time in the extensive aerobic zone during Macrocycle Two. The percentage time spent in the recovery zone during Macrocycle Two and Three was only 5.5 % and 7.2 % respectively. The extensive endurance training during Macrocycle Two was 40 % of the total training during Macrocycle Three, CS2 only trained 22.6 % of his time in the extensive endurance zone. Percentage of training time spent in the intensive aerobic zone was 24.5 % and 20.2 % respectively for Macrocycle Two and Three. During Macrocycle Three 57.9% of his training time was spent in the anaerobic zone, with 26.7 % in Macrocycle Two. This indicates that relatively too much training time was spent in the anaerobic zone during Macrocycle Three.

Training Summary

Graph 104 is an illustration of the breakdown of training spent in the three main training modes, i.e. road training, spinning classes and roller training during the three macrocycles.

Graph 104. Time spent in training modes (road, track and gymnasium) for CS2 (First, Second and Third Macrocycles) during Weeks 1-18 of each Macrocycle.



Time spent doing road work increased with 250 % from the First Macrocycle to the Third. It needs to be remembered that CS2 was injured and off his bicycle for 8 weeks during the First Macrocycle. Training on the road from the Second to the Third Macrocycle improved by 70.5 %. Training on the track increased from the First to the Third Macrocycle with 122% and from the Second to the Third with 31 %. Time spent in the gymnasium increased from the First to Second Macrocycles, with 118 %, but decreased from the Second to the Third with 21 %.

Feedback on Training

The training log was found to be a nuisance for CS2. He did fill out his training log, but not completely. The heart rate monitor was found to be a better way of tracking the training CS2 did. CS2 did not want to monitor his training and heart rate at competition times or the few weeks before competition, due to fear of the psychological effect of it.

Training Sessions

Track training sessions were conducted as his coach had planned. Road training was as the coach decided. Problems arose with CS2's working schedule, exams and time to train. In the First Macrocycle, CS2 did a lot of upper body gymnasium work due to his injury. This resulted in a lot of muscle mass in his upper body and an increase in body mass. Increase in body mass can be detrimental for road race performance especially if it is a hilly course. He designed his own gymnasium workouts.

Training Camps

The training camp in July, 2004, seemed to have a positive influence on CS2. The fact that no working commitments could hinder his training plus he had the company of training partners, a coach for individual attention, as well as sufficient rest time seemed to have a positive effect.

Sports Medicine Services and Products

The only time that financial support was available for CS2 for sports medicine services and products was during the Third Macrocycle. Some of the sports medicine services were required by DISSA, such as a medical evaluation, nutritional evaluation, visual evaluation as well as a psychological evaluation. These were conducted at the start of the Third Macrocycle. CS2 continued massage sessions at least once every alternate week.

Conclusion

To conclude, great improvement in training time, training load etc. is seen, but a systematic way of increasing the training time was not applied. The following is a short summary of the selected factors managed during the study.

Direct Factor	Score*	Reasons
Performance Assessment	4	No specific goals for competition regarding placing or medals were set. Personal best performances were the most important. All laboratory assessments were completed. Testing after competition should be reconsidered due to lack of motivation at the end of a macrocycle. This can be seen in March 2004, especially.
Periodised Planning of Training	2	This is one of the factors that CS2 needs to improve if he wants to improve his performance. A great amount of his training time is spent in the anaerobic training zone. The planning of when to increase training load, as well as frequency and volume of training needs to be systematized.
Feedback on Training	4	Feedback on training improved from Macrocycle One to Macrocycle Three. The use of training logs was not successful, but the heart rate training feedback was. Communication between the coach and the investigator as well as with CS2 definitely improved towards the end of Macrocycle Three.
Training Sessions	3	There was a greater emphasis on road training for CS2 towards the end of the Third Macrocycle. Although an increase in track training resulted in a decrease of road training, it should just be more guided that the road training should be spent at lower intensities and the track replace the high intensity road training. More emphasis should be put on competing in races especially during the pre-competition phase, where no competition training is visible in the Third Macrocycle.
Training Camp	4	The most successful training camp was the July 2004 residential training camp. The fact that CS2 had training partners, intensive coaching and no working commitments definitely was beneficial for him.
Sports Medicine Services & Products	4	The support during the Third Macrocycle was good. It is suggested that CS2 should be able to benefit continuously from Sport Medicine Support.

* Rating scale from 1 (poor) to 5 (excellent).

Chapter Six

Report of Case Study Three

Personal Background

Case Study Three (CS3) is a 22 year old male, cyclist competing in Division 4. Personal information was gathered during interviews with the cyclist. His primary classification is C7 and his type of cerebral palsy is spastic. He is hemiplegic with the right side affected. He had surgery to lengthen his Achilles tendon. Before the age of 6 he suffered from asthma and other allergies. During the ages 8-15 he had a few epileptic fits, and then again twice in 2003 at the age of 21.

From a young age he has had professional support in the form of physiotherapy, occupational therapy and speech therapy. The speech therapy continued until the age of fifteen years. His first official school sports were cricket, athletics and hockey between the ages of 8 -15 years. He started cycling at the age of 14 years when he also competed in cycling for the first time. His father coached him until middle 2003 when he had a road coach and he started to train with a squad.

Year	Achievements
2002	World Championships – Germany 9 th in Road Race 11 th in Road Time Trial 6 th 3000 m Pursuit 7 th 1 km Time Trial
2003	European Championships – Czech Republic 6 th in Road Race 6 th in Road Time Trial 6 th 3000 m Pursuit 5 th 1 km Time Trial
2004	Paralympics – Athens 9 th Combined Road Race and Time Trial Results 6 th 3000 m Pursuit 8 th in Combined Class1 km Time Trial but 4 th in his own class.

His list of achievements at international level is evidence that he is an elite cyclist.

In order to determine how to support his training, a short summary of the training methods he used as well as the support system he had, was made as a part of a needs analysis. The following is a summary of the preliminary information used to provide a framework for the development of a strategy to enhance the cycling performance of CS3:

Usual competitions each year	<ul style="list-style-type: none"> • South African National Championships for the Physically Disabled. • South African Able-bodied Cycling Championships. • World Championships / International event. • Able-bodied League Races
Training intensity	km/h and perceived effort
Different training modes	Gymnasium work, road training, track training, home trainer.
Bike Set up	Has been set up specific for him.
Coach	During the First Macrocycle his father was his coach. Elrick Kulsen assisted him with track training. During the Second Macrocycle he got a coach, specializing in road racing. He started training with a group.
Coach's qualifications	He himself was a national cyclist, and still competes.
Training facilities	Road training and home trainer. Closer to competition he made special arrangements to get to a cycling track.
Professional support	Limited Sport Science support through Stellenbosch University in cooperation with DISSA, when funds were available.

Modifications to CS3's Evaluation and Training

Because training must be customised at the elite level, it is necessary to modify evaluations and interventions to each specific cyclist's needs. The unique events in each cyclist's daily life will also modify pre-planned evaluation and training decisions.

Daily Monitoring

Daily monitoring during all three macrocycles was based on CS3's training log as well as heart rate monitor data. Heart rate data was used to determine intensity, volume (duration in time) and frequency of training and CS3's daily training log was used to provide the rest of the data. Heart rate training data was not received on a consistent basis, but only when CS3 could find time to download the data and email it. It was at least once a month, and sometimes more frequently.

Physiological Monitoring

The following adaptations were made to the general evaluations:

1. Anthropometric measurements.

Measurements were taken on the left side of his body, due to the right side hemiplegia.

2. Wingate Test.

No specific adaptations to the testing protocol. CS3 was tested against a resistance of 9.8 % of body weight.

3. Incremental test to exhaustion.

The following testing protocol was used:

Start load: 210 Watts.

Increments: First increment 30 Watts, thereafter 20 Watts.

Time of increments: Each increment was 150 seconds.

4. 1-hour distance trial.

No adaptations.

5. 1 km & 3 km time trial.

No adaptations.

6. 7.5 km time trial.

Did not do the test.

Individual Interventions

A broad layout of a periodised training plan during all cycles as well as training feedback was given to CS3.

Group Interventions

CS3 attended both group interventions (as described in Chapter Three).

Physiological Monitoring (Evaluation and Daily Training) First Macrocycle: April, 2003 – October, 2003

During the first consultation meeting with CS3, the nature of the research project was explained. CS3 expressed enthusiasm for participation and signed an informed consent form (see Appendix A). A short needs analysis regarding his access to coaching, different training modes, training programmes, and use of goal-setting in 2003 were discussed.

The first time period was set from the South African National Championships for the Physically Disabled held in April, 2003 to the European Championships Cycling Championship in September, 2003. This period was 21 weeks.

Direct Factors Targeted during the First Macrocycle

The research question guiding this study focused on the management of selected direct factors important for sport performance for elite cyclists with cerebral palsy. The following direct factors were identified and managed in the following way:

1. **Performance Assessment:** Due to the nature of this cycle, competition performance was evaluated for CS3 in April, 2003; July, 2003 as well as October, 2003. Continuous performance assessment in the laboratory was done one week post competition in April and October, and after 12 weeks of training in July.
2. **Periodised Planning of Training:** Before this study, no periodised training planning took place. A basic layout of training was given to CS3 according to the physiological goals for the First Macrocycle.
3. **Feedback on Training:** This was introduced to CS3 for the first time in his career. Explanations of how to complete the training log after training each day was given. The training log was important to evaluate the volume and mode of training as well as the duration.
4. **Training Sessions:** CS3's main training mode was road cycling.

5. Training Camps: A short training camp was the first encounter with CS3. The study was explained as well as the importance of a training log, periodisation of training and different training techniques to develop an allround cyclist.
6. Sports Medicine services and products: No funding available for support in this macrocycle.

Goals for the First Macrocycle

The primary goal for the First Macrocycle was to prepare for the European Cycling Championships for Persons with Disabilities in Prague, Czech Republic, at the end of September, 2003. An overall evaluation of training and performance was the goal for this cycle.

Physiological Evaluations

The differences in the laboratory testing were as follow.

Anthropometry

Table 53 is a summary of the anthropometric measurements for CS3 during the first macrocycle.

Table 53. Anthropometric measurements of CS3 (First Macrocycle)

Date	April 2003	July 2003	October 2003
Age (yrs)	19	20	20
Body mass (kg)	61.6	61.5	63.7
Height (cm)	170.8	170.3	170.5
% Fat	8.2	8.6	7.2

Body mass Body mass for CS3 was constant for the first 12 weeks, after which he gained 2.2 kg.

Height The height of CS3 varied little, with a range between 170.3 – 170.8 cm.

Fat percentage His fat percentage changed from April – July with 0.4 %, and changed towards October by -1.4 %., despite increased body mass.

General CS3's BMI of 21.4 kg/m² in October compares well with the recommended BMI for cyclists (\pm 22 kg/m² for time trailers and 19-20 kg/m² for climbers,

Lucia et al., 2001). The increase of body mass, but a simultaneous decrease in fat percentage indicates an increase in muscle mass.

Incremental Exercise Test to Exhaustion

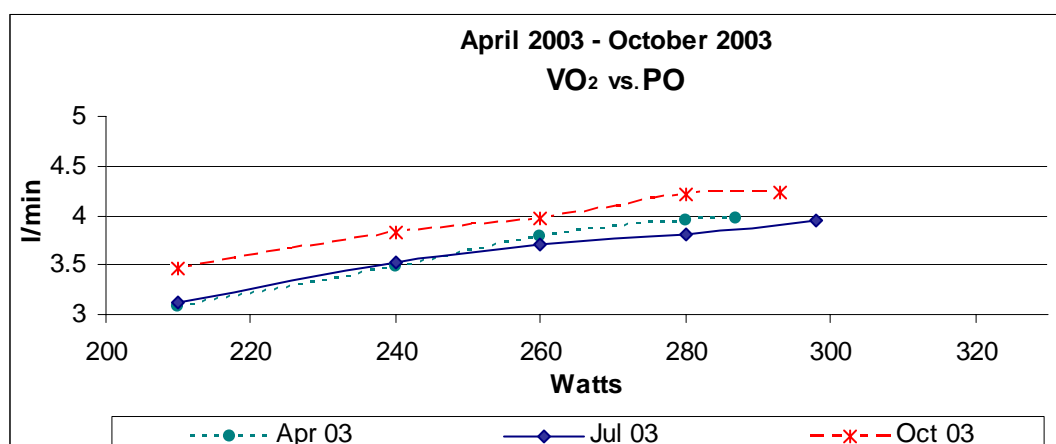
The results of this test are presented in Table 54.

Table 54. Results of the incremental exercise test to exhaustion for CS3 (First Macrocycle)

	April 2003	July 2003	October 2003
Total time of test (min:s)	10:32	12:17	11:44
VO ₂ max (l/min)	3.96	3.94	4.24
VO ₂ max (ml/kg/min)	62.5	62.4	66.7
HR _{max} (bpm)	206	211	210
Peak power (PPO) (Watts)	287	298	298
Peak power: Weight (W/kg)	4.70	4.72	4.69
Max lactate (mmol/l)	11.2	16.7	11.2
La ₂ (Watts)	73.5	94.5	Start
La ₂ (HR)	153	160	129
La ₄ (Watts)	225	244	225
La ₄ (HR)	173	190	184
RER	1.09	1.16	1.07
RER of 1 (Watts)	226	212	240
RER of 1 (HR)	171	174	191
Time cycled at RER above 1 (min:s)	6:50	10:07	6:44

Graph 105 illustrates the efficiency of pedaling expressed as the relationship between oxygen used and work done (watts of pedaling).

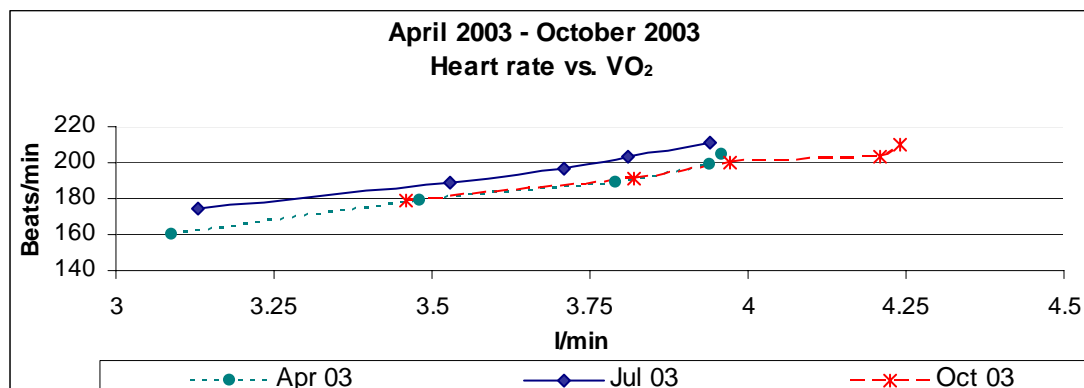
Graph 105. Pedaling efficiency for CS3 (First Macrocycle)



- The April plot indicates the same pedaling efficiency as July at the easier workloads.
- The July testing resulted in the lowest VO_2max , but the best pedaling efficiency of the three tests. A 6 % increase in PPO is visible.
- The October plot indicates a decrease in pedaling efficiency at all workloads, with an increase of 6 % in PPO (Watts) from April to October, but no increase from July to October. The VO_2max (l/min) increased by 7.6 % from July to October. The October testing was completed after the competition time. The decrease might be due to detraining after competition or lack of high intensity training close to competition time.

Graph 106 illustrates the heart rate relative to the oxygen uptake (VO_2) required.

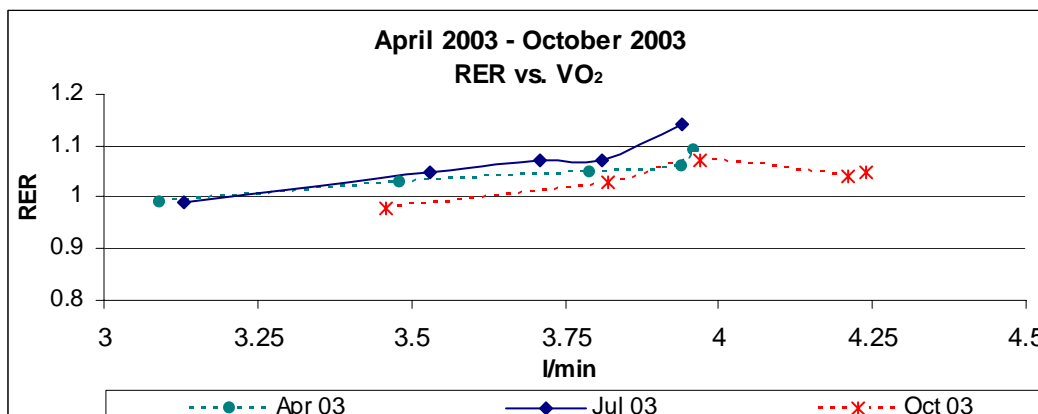
Graph 106. Heart rate for CS3 (First Macrocycle)



- The linear increase in the heart rate was followed up to 3.96 l/min in April.
- A linear relationship during July is also visible. HR_{max} for July was 211 bpm. The HR efficiency during the First Macrocycle was less efficient during July.
- October indicated the lowest heart rate for VO_2 just before 4 l/min during the First Macrocycle. Maximum HR achieved during October was 210 bpm, which was not higher than April but occurred at higher oxygen consumption.

Graph 107 presents the relationship between the respiratory exchange ratio (RER) and the oxygen uptake (VO_2).

Graph 107. Respiratory exchange rate for CS3 (First Macrocycle)

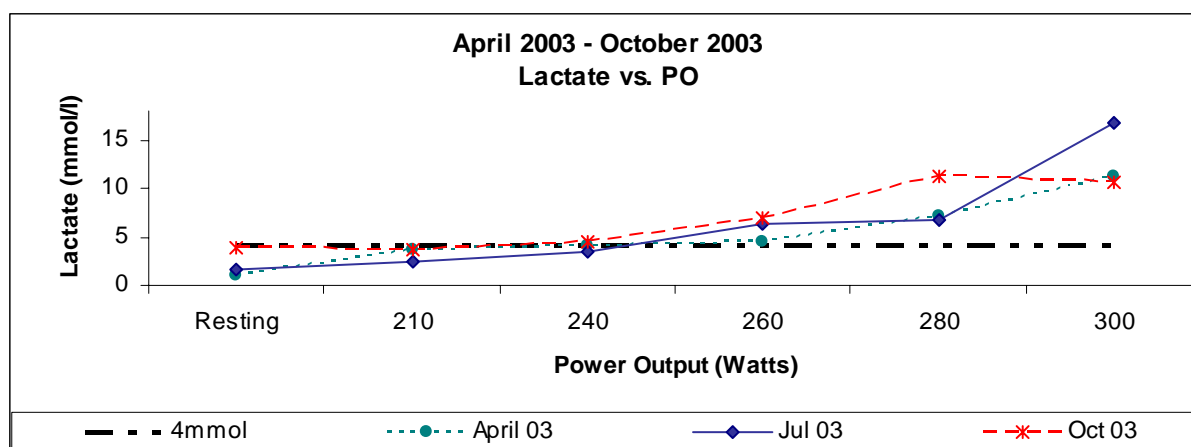


A RER under 1 indicates a desirable level in CS3's capacity to use mainly oxygen especially fat oxidation to produce energy for the cycling action. A lower RER indicates greater fat vs. carbohydrate oxidation. In contrast, a RER above 1 indicates hyperventilation associated with anaerobic metabolism and fatigue.

- During April CS3 started the test with a RER close to 1. CS3 was therefore not well adapted to use fat oxidation as source of energy. This was unlikely to be due to hyperventilation as a result of anxiety because CS3 had been tested before several times.
- RER was also high during the incremental test in July, when the highest RER was recorded
- The October testing indicated that CS3 had a slightly higher capacity to use fat as energy source with a starting RER lower than 1, and a RER of 1 was achieved before the second workload.

Graph 108 is an illustration of blood lactate concentrations (mmol/l) at each workload (Watts) during the incremental test.

Graph 108. Blood lactate accumulation for CS3 (First Macrocycle)



CS3 had a good capacity to produce work under relatively high levels of blood lactate accumulation with a maximum of 16.7 mmol/l achieved in July. During this study, the onset of blood lactate accumulation (OBLA) at 4 mmol/l was used to monitor improvement.

- OBLA was achieved at 78 % of PPO (225 Watts) during April.
- OBLA was achieved at 82 % of PPO (244 Watts) in July. This indicates the highest percentage of PPO as well as the highest Watts at OBLA for Macrocycle One.
- OBLA was achieved at 75.5% of PPO (225 Watts) in October.

Wingate Test (sprint power and resistance to fatigue)

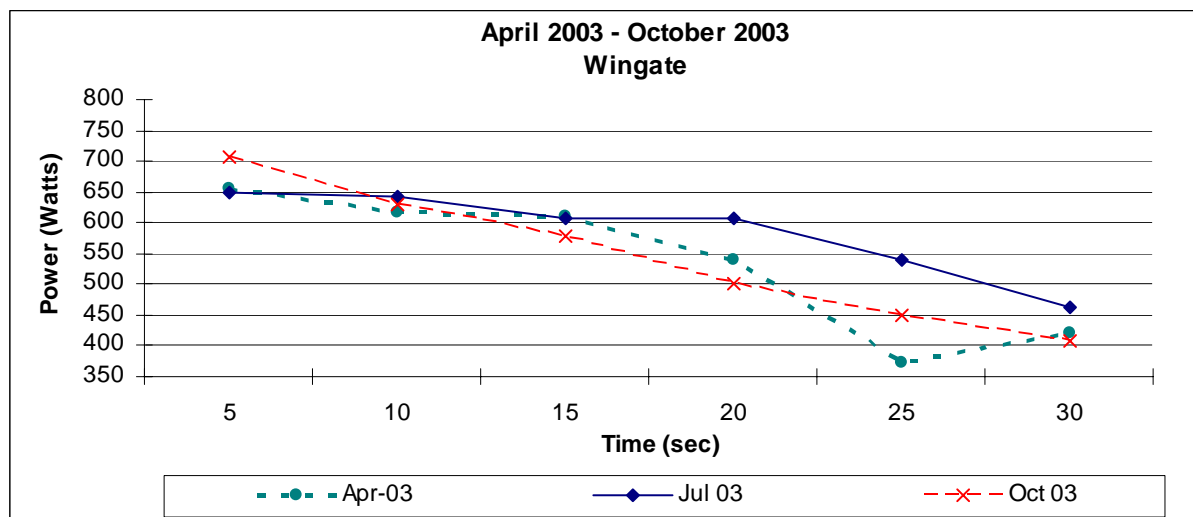
Results of the 30 second Wingate test are presented in Table 55.

Table 55. Values obtained during the 30 second Wingate test for CS3 (First Macrocycle)

	April 2003	July 2003	October 2003
Resistance	9.8 % / BW	9.8% / BW	9.8 % / BW
Body mass (kg)	61.6	61.5	63.7
Peak sprint power (Watts)	654	650	706
Relative peak sprint power (W/kg)	10.6	10.6	11.1
Avg sprint power (Watts)	536	585	546
Relative avg sprint power (W/kg)	8.7	9.5	8.6
Minimum sprint power (Watts)	373	464	409
Avg sprint power / peak sprint power (%)	82	90	77
Fatigue index (W/s/kg)	0.13	0.10	0.16

Graph 109 is an indication of the average power output (Watts) during each 5 seconds of the Wingate test.

Graph 109. Sprint power and resistance to fatigue for CS3 (First Macrocycle)



Peak and mean sprint power is important for tactical attacks during a road race and very important for the track events (1 km time trial and 3 km pursuit). The peak sprint power (first 5 sec) is important during the start of the track events and the mean sprint power indicates the capacity to sustain maximal sprint power. Track racing is about power output and the capacity to maintain it.

- CS3's best mean sprint power during this macrocycle was in July. His peak sprint power changed with less than -1 % but his mean sprint power increased with 9 %. This indicates an increased ability to sustain his power over the 30 seconds. This may be due to an alteration in pacing strategy as a result of more experience with the test.
- Peak sprint power also increased from April to October with 8 %. His mean sprint power decreased from July to October with 7 %. This decrease might be due to detraining after the tapering before the competition or due to a lack of motivation as the testing was conducted after the competition.

1-Hour Distance Trial

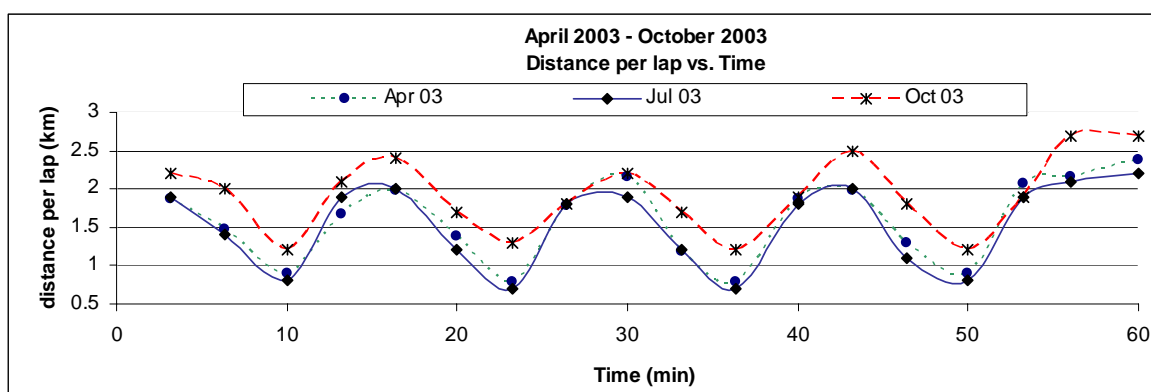
The results of this test are presented in Table 56.

Table 56. Values obtained during 1-hour distance trial for CS3 (First Macrocycle)

	April 2003	July 2003	October 2003
Total distance (km)	28.7	27.5	34.5
Avg cadence (rpm)	79±12	70±15	79±10
Total distance 4% incline (km)	5.3	4.9	7.2
Avg cadence 4% incline (rpm)	78±7	61±9	73±10
Total distance 8% incline (km)	3.4	3	4.9
Avg cadence 8 % incline (rpm)	63±1.3	49±5	68±2
Avg heart rate (bpm)	183±12	193±11	182±15
Highest heart rate (bpm)	196	205	206

Total Distance. Graph 110 illustrates the split distance for each lap. For interpretation of the graphs, remember from the method section that each lap represents 3 minutes and 20 seconds. The first lap was a flat distance, the second a 4% gradient hill, the third lap a 8% gradient hill, followed by 2 flat laps, before the first 4 % gradient commenced again and the sequence was repeated four times. The last 10 minutes was flat. The peak distances were during the flat part of the test and the shorter distances during the climbs.

Graph 110. Lap Distance (km) during 1-hour distance trial for CS3 (First Macrocycle)



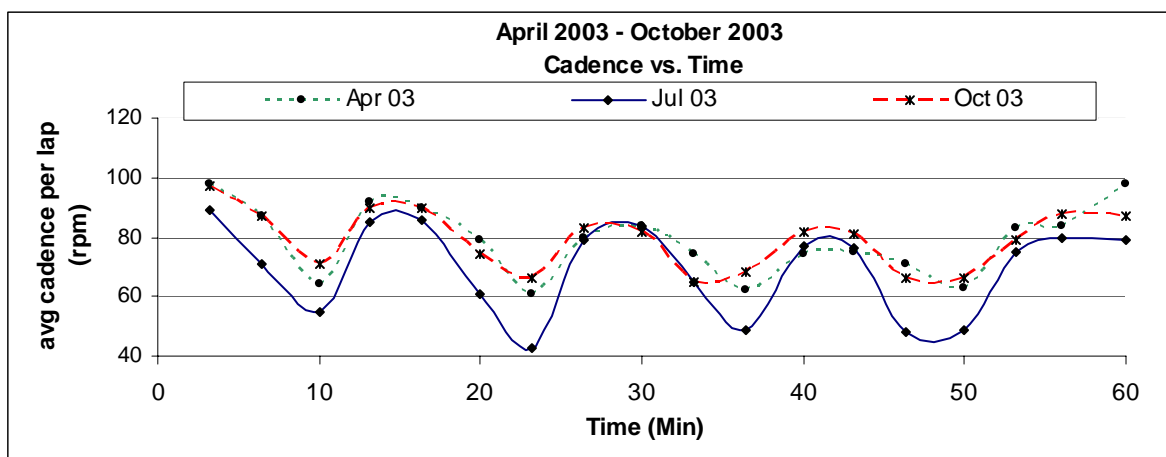
(Rationale for connecting the data points was presented in Chapter Three.)

- During July, the distance covered decreased with 1.2 km, with a total distance on the 4% hill 4.9 km and 3 km on the 8% hill. This indicates that 67 % of the decrease in distance between April and July was found on the hills.

- The total distance covered during October showed a 20 % increase in distance since April. The total distance covered over the four 4 % gradient hill in October, was 1.9 km more than in April, which is a 36 % increase in distance. The total distance for the four 8 % gradient hills was 1.5 km more than in April, a 44 % increase. This indicates that 59 % of the distance increase was on the hills. The graphs indicate a clear improvement in CS3's capacity to accelerate over the last 6:40 min:s, that indicates good pacing strategy.

Cadence (rpm). Graph 111 is an illustration of the cadence (rpm) averaged per lap over the period of time. The cadence was higher on the flat part of the race and lower on the hills.

Graph 111. Cadence (rpm) selection during the 1-hour distance trial for CS3 (First Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

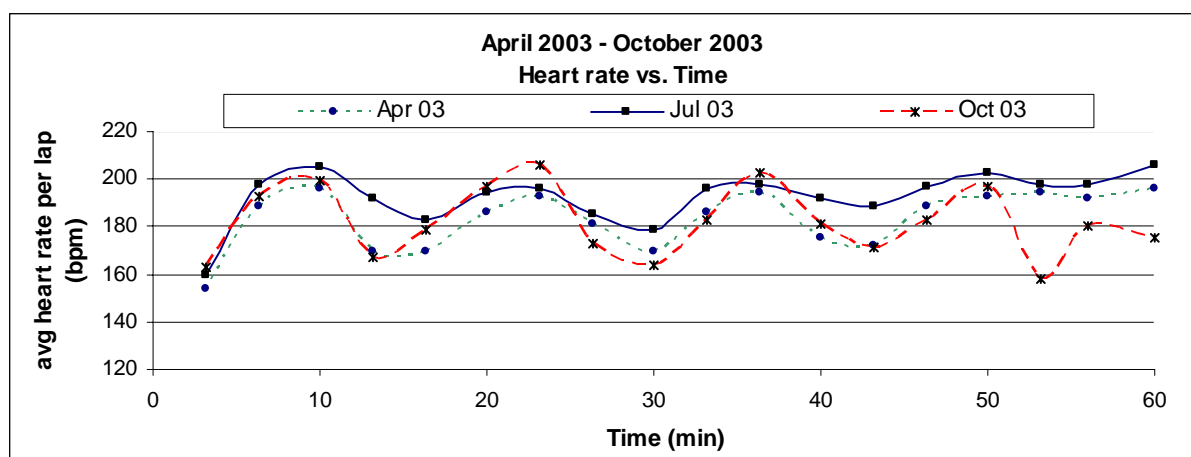
The graph above indicates that CS3 had a similar cadence selection over the three test periods average between 70 and 79 rpm.

- During April, the average cadence on the 4 % gradient hill was 78 rpm, but the cadence selection of the 8 % gradient hill illustrated a negative change to 63 rpm in April.
- The average cadence for July was 70 rpm, with a cadence of 61 rpm on the 4 % hill and a cadence of 41 rpm on the 8% hill. This indicated a change of cadence on the 4 % hill of -17 rpm and on the 8 % hill a -14 rpm cadence, explaining his poor performance.

- The average cadence for October was 79 rpm, which was close to that in April, but the distance covered was more. This indicated that CS3 was able to cycle at a bigger gear at the same cadence to allow the greater distance.

Heart Rate (bpm). Graph 112 illustrates the heart rate (bpm) averaged for each lap over the time period of the test.

Graph 112. Heart rate (bpm) during 1-hour distance trial for CS3 (First Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

The incremental exercise tests indicated that CS3's maximum heart rate is 211 bpm and this was taken as HR_{max} .

- CS3 averaged 87 % of his HR_{max} during April and a highest HR of 196 bpm was achieved. The average HR is 105 % of HR_{OBLA} achieved in April. The highest average HR was achieved during the 3rd lap in April.
- In July, CS3 averaged at 91 % of HR_{max} , and 102 % of HR_{OBLA} achieved in July. Therefore his performance was not due to lack of motivation.
- In October, CS3 averaged at 86% of HR_{max} and 99 % of HR_{OBLA} achieved in October. Of interest is the fact that during April and July, CS3 was able to increase the heart rate over the last ten minutes for a final sprint to the finish, which he was not able to do during October. This is difficult to explain.

Summary of 1-Hour Distance Trial. October indicates a great improvement in distance, with nearly the same cadence selection as April, and with a higher speed over the last 10 minutes, but a lower heart rate at the same time. The improvement on the hills in October is indicative of his muscular endurance capacity in October. The main improvement in this test was the distance covered during the flat terrain in the October testing.

1 km Time Trial

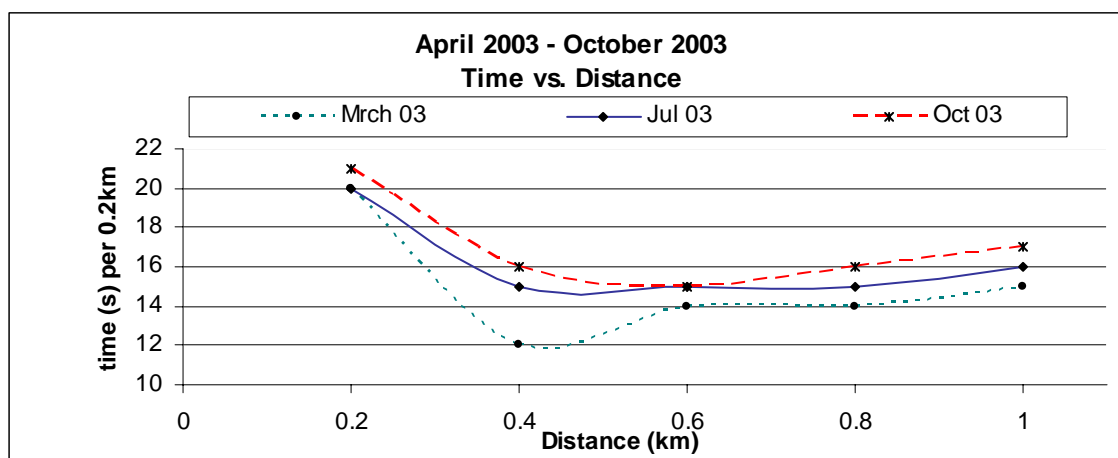
Results of the 1 km time trial are presented in Table 57.

Table 57. Results during the 1 km time trial for CS3 (First Macrocycle)

	April 2003	July 2003	October 2003
Gear selection	88	90	90
Time (min:s)	1:16.8	1:17.8	1:20.6
Avg cadence (rpm)	131±9	116±7	Faulty equipment
Avg speed (km/h)	46.9±5	46.3±5	44.7±7
Avg heart rate (bpm)	187±28	192±30	187±17
Highest heart rate (bpm)	205	210	199

Time / Distance. Graph 113 illustrates the time taken (s) for each 0.2 km during the 1 km time trial.

Graph 113. Time taken (s) for each 0.2 km during the 1 km time trial for CS3 (First Macrocycle)



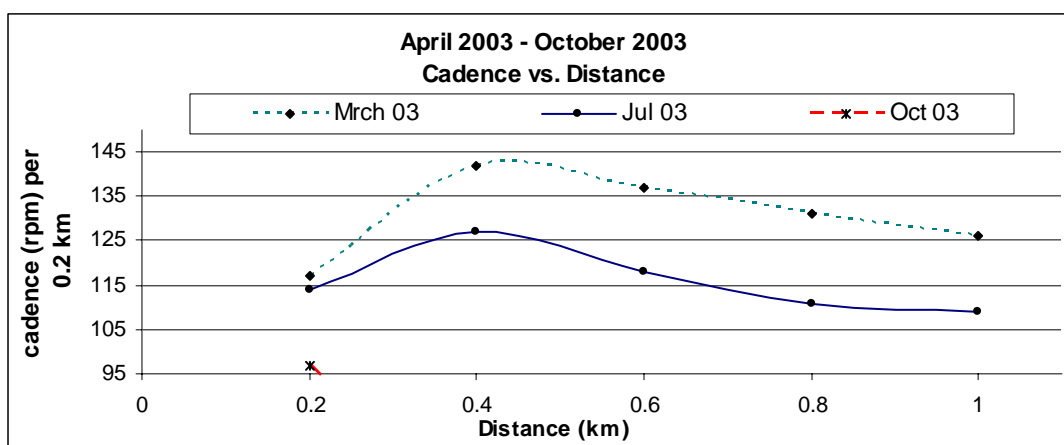
(Rationale for connecting the data points was presented in Chapter Three.)

This graph is an indication of the 1 km track time trial capacity of CS3 and the tactics he used.

- The best time of 1:16.8 was achieved during April. The tactics used by CS3 included the fastest start, especially in the 2nd 0.2 km and then a negative change in speed towards the end. The average speed achieved in April was 46.09 km/h.
- July indicated the same speed over the first 0.2 km, but he never achieved the same maximal speed as in April. The average speed over the 1 km was 46.3 km/h.
- October showed the slowest start as well as the slowest speed throughout the 1 km. The average speed obtained in October was 44.7 km/h. This is in agreement with the decrease in ability to sustain high average watts in the Wingate test.

Cadence (rpm). Graph 114 illustrates the cadence (rpm) averaged per 0.2 km lap during the 1 km time trial.

Graph 114. Cadence (rpm) selection during 1 km time trial for CS3 (First Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

* Cadence measurement for October was faulty.

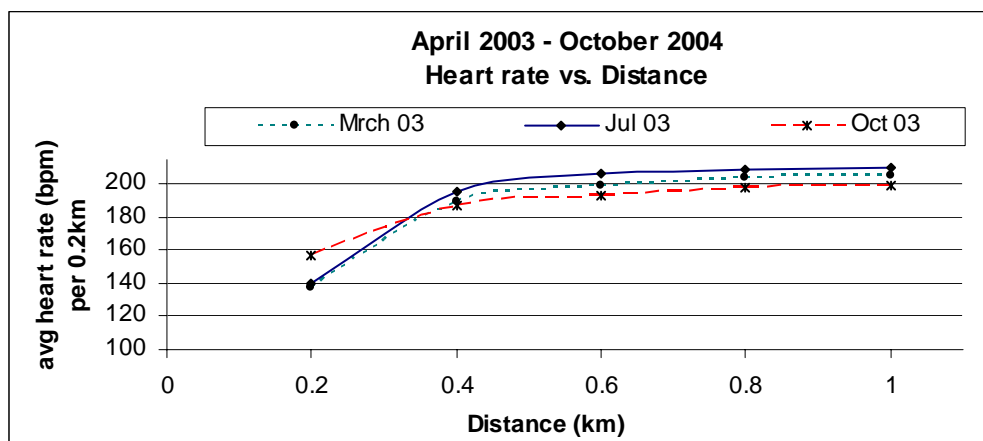
The fact that no gear change is possible on a track bike, means that gear selection is important when considering the cadence used.

- The April graph showed the fastest average cadence of 131 rpm. Maximum cadence was achieved slightly after the 0.4 km mark with the peak, a cadence of 142 rpm.

- July indicated a lower cadence throughout the 1 km, with an average cadence of 116 rpm.

Heart Rate (bpm). Graph 115 illustrates the heart rate (bpm) averaged for each 0.2 km over the distance (km) covered.

Graph 115. Heart rate (bpm) during 1 km time trial for CS3 (First Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

- It is interesting to note that the July graph indicated a higher heart rate for the whole duration of the test, although the speed and cadence was slower. This can be due to the bigger gear he needed to turn over, that resulted in a greater heart rate intensity, but not always faster times.
- The October graph indicated a higher heart rate intensity over the first 0.4 km, whereafter it decreased to the lowest of the three tests. An average heart rate of 187 bpm was achieved, and this was reflected in poor performance.

Summary of 1 km Time Trial. The main difference in the 1 km time trial, was the capacity to maintain the speed and therefore muscle or speed endurance (Friel, 2003). The fact that CS3 was cycling at an increased heart rate intensity in July, could have been due to the fact that his legs needed to increase the power-output during the duration of the test due to the bigger gear. The high cadence in April was an indication that CS3 had the ability to cycle at high cadence and that his cerebral palsy did not affect his ability.

3 km Time Trial

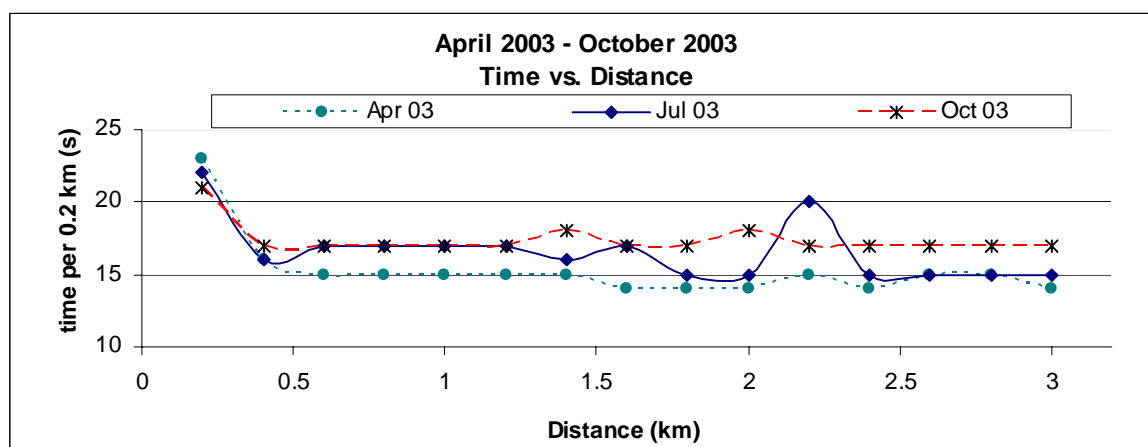
Results of the 3 km time trial are presented in Table 58.

Table 58. Results during the 3 km time trial for CS3 (First Macrocycle)

	April 2003	July 2003	October 2003
Gear selection	88	90	90
Time (min:s)	3:49	4:09	4:21
Avg cadence (rpm)	122±9	108±3	104±2
Avg speed (km/h)	47.2±5	43.4±3	41.38±2
Avg heart rate (bpm)	192±15	190±26	188±11
Highest heart rate (bpm)	206	207	201

Time / Distance. Graph 116 illustrates the time taken (s) for each 0.2 km over the distance (km) achieved during the 3 km time trial.

Graph 116. Time taken (s) for each 0.2 km during the 3 km time trial for CS3 (First Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

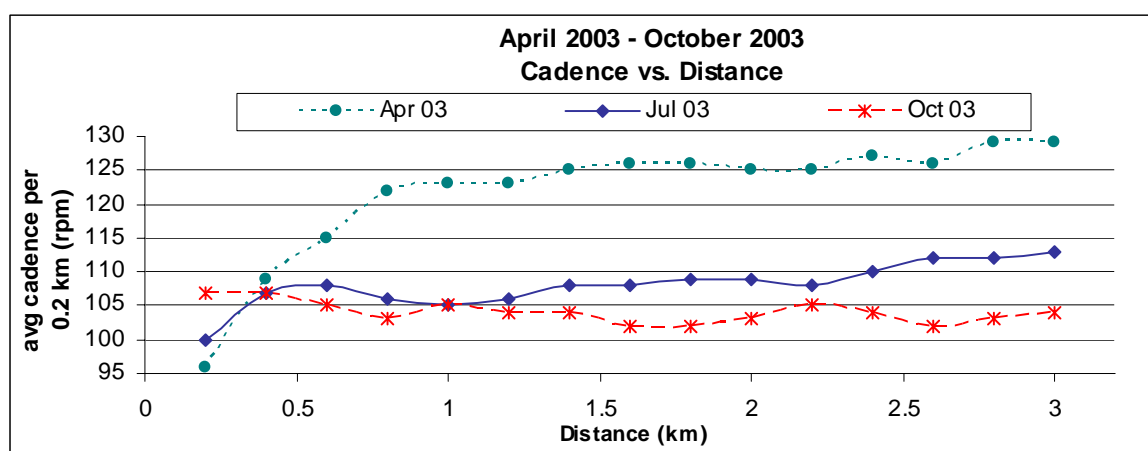
This graph is an indication of the riding capacity during the 3 km track pursuit as well as the tactics used during the particular test.

- April data indicated the fastest average time and therefore speed achieved during Macrocycle One, despite the slowest start over the first 0.2 km. His pacing was almost constant since he reached maximal speed at 0.5 km. An average speed of 47.2 km/h was achieved.

- During July, CS3 started off faster than in April. Between 2 km and 2.4 km a decrease in speed was notice. This may indicate a lack of concentration.
- October indicated the fastest start over the first 0.2 km but, the slowest average speed of 41.4 km/h.

Cadence (rpm). Graph 117 illustrates the cadence (rpm) averaged for each 0.2 km during the 3 km time trial.

Graph 117. Cadence (rpm) selection during 3 km time trial for CS3 (First Macrocycle)



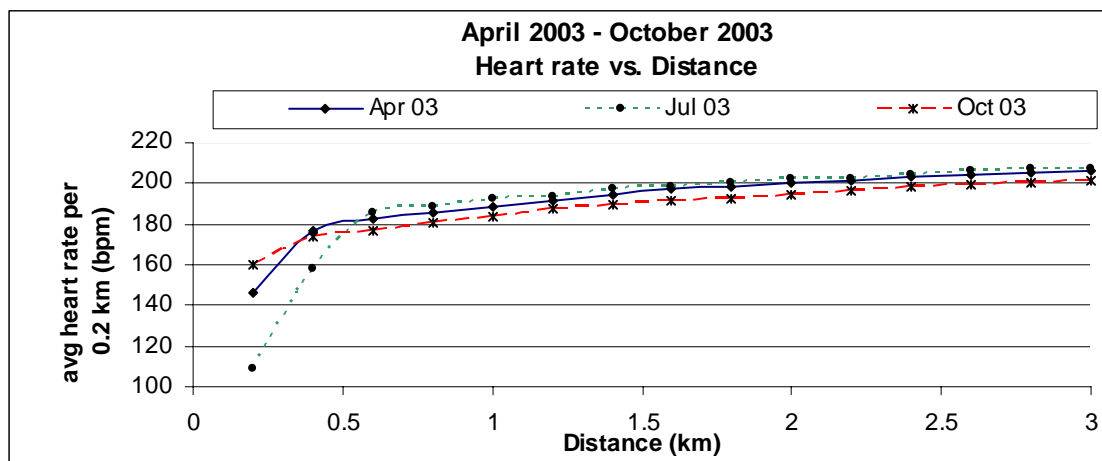
(Rationale for connecting the data points was presented in Chapter Three.)

The fact that no gear change is possible on a track bike, the gear selection is important when consider the cadence used. During the July and October the gear selection was 90, with a gear of 88 in April.

- Although April data indicated the slowest cadence at 0.2 km, the average cadence is by far the highest compared to the other two tests. The average cadence was 122 rpm.
- July data indicated a faster cadence at 0.2 km than April, it was slower than in October. The average cadence of 108 rpm is slower than in April, but faster than in October. He increased his cadence over the last 1 km, which indicates good pacing strategy.
- October data indicated the fastest cadence at 0.2 km but, the cadence decreased all the way and an average cadence of 104 rpm was achieved.

Heart Rate (bpm). Graph 118 illustrates the heart rate (bpm) averaged per each 0.2 km over the distance (km) covered.

Graph 118. Heart rate (bpm) during 3 km time trial for CS3 (First Macrocycle)



Although heart rate during such short and intense event is not really indicative of the intensity (Powers & Howely, 2001), it is interesting to compare the different graphs.

- During April, although the heart rate started lower over the first 0.6 km, it was increased to the highest average heart rate of the three tests.
- July showed a slight negative change in average heart rate (2 bpm) but a really much poorer performance.
- The October average heart rate of 188 bpm and a highest of 201 bpm, indicated the highest starting heart rate over the first 0.4 km, but the slowest average heart rate thereafter.

Summary of 3 km Time Trial. It is interesting to note that the heart rate followed the same tendency as the cadence and therefore the speed. The April performance was best and started with the lowest heart rate, cadence and speed, but ended up with the highest average heart rate, cadence and speed. This is indicative of the tactics used by CS3.

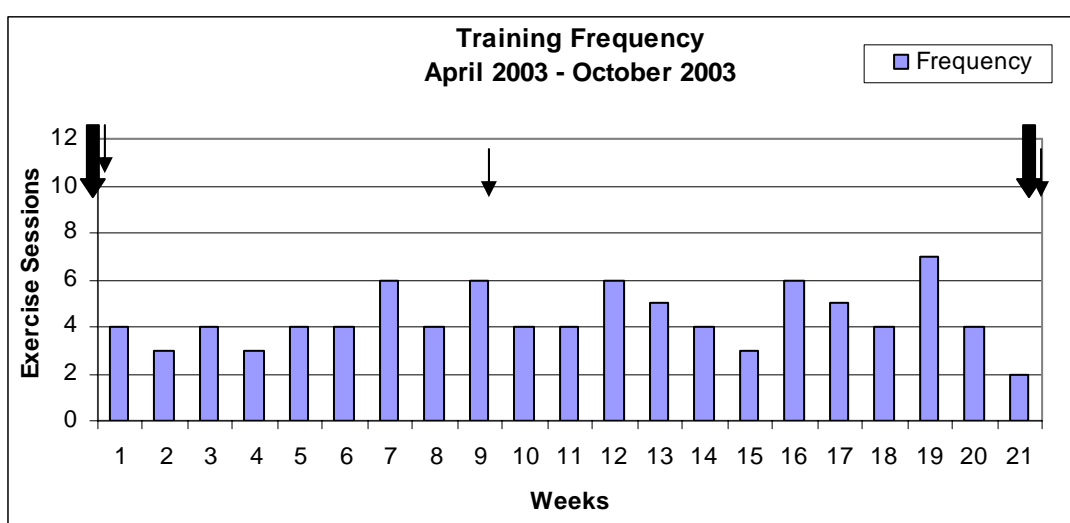
Training

During the First Macrocycle, the training logs and heart rate data retrieved from CS3 were used to determine his training intensity, volume, frequency and the mode of training. He competed in week 21 at the European Championships in Czech Republic.

Training Frequency

Graph 119 illustrates the exercise sessions per week for the First Macrocycle.

Graph 119. Training frequency for CS3 (First Macrocycle)



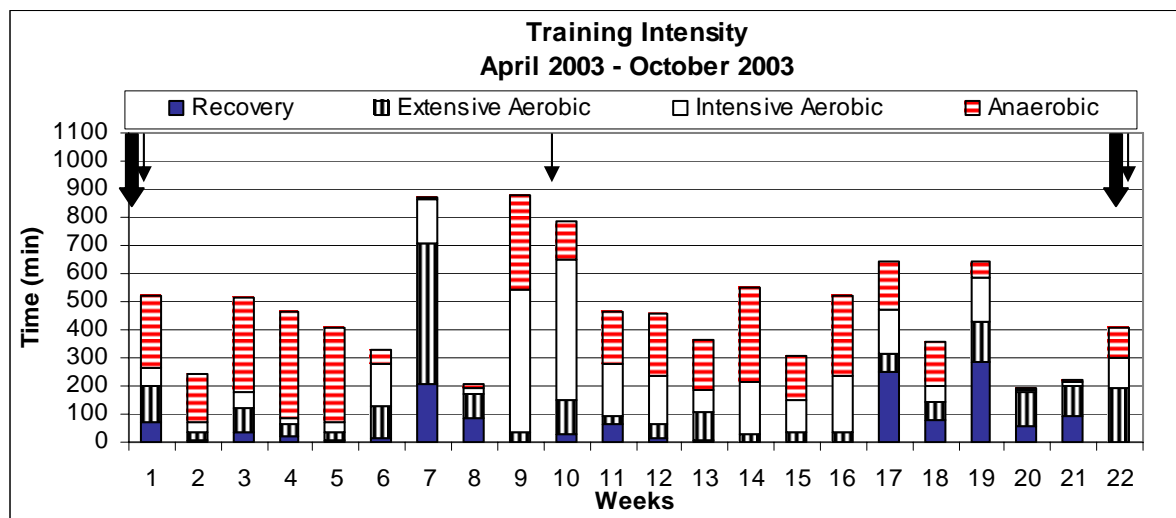
↓ Indicative of the competition times. ↓ Indicative of testing times.

CS3's training frequency showed a constant average of 4.4 sessions per week. The lowest frequency except for the competition week in Week 21 was 3 sessions per week, with the highest frequency in Week 19 with 7 sessions.

Training Intensity

CS3 used a heart rate monitor (Polar S720) to capture his heart rate and therefore his training intensity. Graph 120 is an indication of the number of sessions at different training intensities during each week.

Graph 120. Training intensity for CS3 (First Macrocycle)



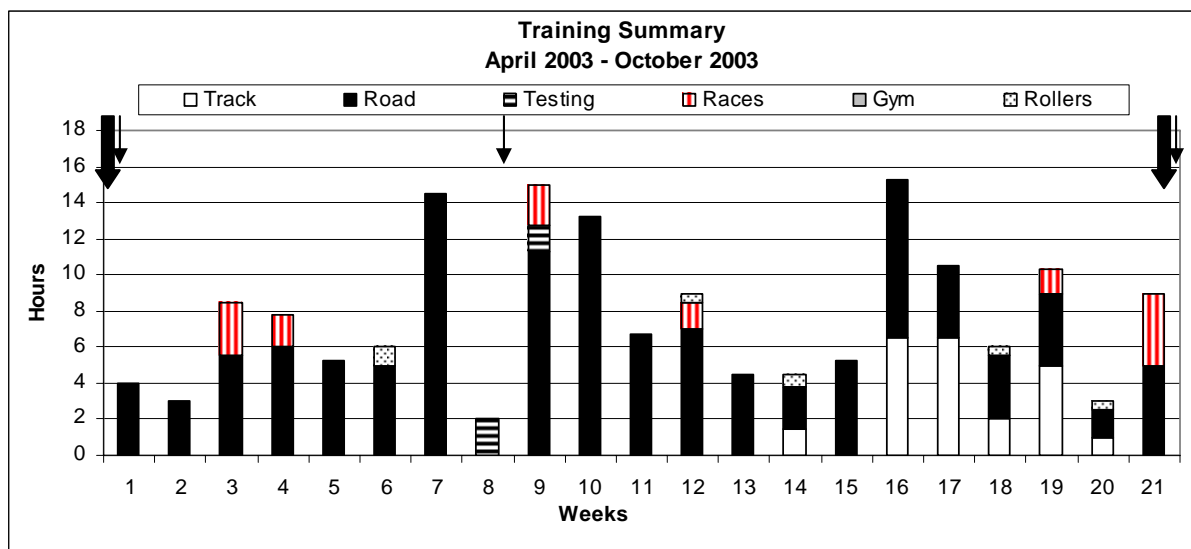
↓ Indicative of the competition times. ↓ Indicative of testing times.

Training during the first 6 weeks of Macrocycle One, was done at a high intensity. He spent 61 % of his training time at heart rate intensities higher than 85 % of HR_{max} . His average training time was about 7 hr per week. During the next 6 weeks, an attempt to train at lower heart rate intensities was made and especially in Week 7 a great amount of training was done in the extensive aerobic zone (70-80 % of HR_{max}). He still spent percentage wise the most time in the anaerobic zone (25 %), but his extensive endurance increased to 23 %. His training was more balanced between the training zones. During weeks 13-18 his time spent in the anaerobic zone (>85 % of HR_{max}) reached 46 %, and 76 % of his training was done at heart rate intensities greater than 80 % of HR_{max} . During the two tapering weeks and competition week, he spent 77 % of his training time below 80 % of HR_{max} . Descriptions of the sessions would have been helpful in determining if he did high intensity repetition work, with a lot of recovery in between, or long slow rides.

Training Volume and Training Modes

CS3 noted the different training modes he used to do his training in his training log as well as when he had rehabilitation. Training volume (km) was impossible to determine given that he used so many different modes of training, many of which could not be quantified in km. Hence the volume of training is expressed as duration (hours/week). Graph 121 illustrates the different training modalities used during the First Macrocycle.

Graph 121. Training summary for CS3 (First Macrocycle)



Indicative of the competition times. Indicative of testing times.

The training summary is an indication of the specificity of training as well as the different training modes CS3 used. During weeks 1 – 6 CS3 spent 83 % of his total training time on the road. He also competed in two able body league races, one in Week 3 and One in Week 4. During weeks 7 – 12 his training volume increased, and testing took place in weeks 8 -9. During this time he spent 87 % of his training time on the road. He trained on average about 10 hr per week. During weeks 13 – 18 the training volume decreased to 7.6 hr per week. More time was spent training on the track with 36 % of his training time on the track and 62 % on the road. He did compete in a competition in Week 19 prior to his major competition. His training volume decreased only slightly to 7.3 hr per week, with 47 % of the time on the road and 27 % on the track.

General Summary of Training

During the First Macrocycle, the main focus was to compete at the European Championships. The South African Cycling Championships (able-bodied) was held in June and the competitions mentioned in weeks 3 and 4 were during the Championships. The first 6 weeks were therefore not really general preparation but rather competition phase due to the fact that CS3 wanted to achieve good results. Weeks 7-12 were therefore the time period for base training and the decrease in intensity as well as increase in training volume support this fact. It was also holidays and CS3 had more time to focus on training.

Direct Factors Targeted during the First Macrocycle

The research question guiding this study focused on the management of selected direct factors important for sport performance management. The following rating scale reflects the investigator's perceptions of the degree of success in managing these factors.

Direct Factor	Score	Reasons
Performance Assessment	4	CS3 competed well at the European Championships. All three laboratory assessments were completed with enthusiasm and motivation. The faulty equipment to measure cadence had a slight effect on the cadence feedback in October's 1 km Time Trial.
Periodised Planning of Training	3	The plan was given to CS3. From there it was for him to implement. Although some other factors like the South African Able Body Cycling Championships did slightly change the training plans, he did try and implement the plan. Factors like exams, and holidays, should be taken into consideration when doing a periodised plan.
Feedback on Training	2	CS3 found the training logs a great nuisance and kept a very incomplete training log, but his heart rate data was more complete.
Training Sessions	3	Most of the training sessions were done on the road as part of a group. Specific goals for the training sessions weren't set up. A cycling track is about 35 minutes away, and transport is a problem. It is for this reason that track training only started after Week 13.
Training Camp	4	It served its purpose to explain the importance of planning as well as the study.
Sports Medicine Services & Products	1	No funding available.

Score = Point out of 5, with 0 not achieved, 5 fully achieved.

Physiological Monitoring (Evaluation and Daily Training) Second Macrocycle: October, 2003 - March, 2004

The Second Macrocycle was set after the transition phase following the European Championships in September, 2003, and lasted up to the South African National Championships for Physically Disabled held in March, 2004.

Goals for the Second Macrocycle

The primary aim for this macrocycle was to prepare for the South African National Championship for Physically Disabled. The National Championships served as the trials for the South African Paralympic Team for Athens, 2004. It was critical to perform there at top level.

Direct Factors Targeted during Second Macrocycle

The following direct factors were identified and managed in the following way:

1. Performance Assessment: The only competition evaluation was in March 2004 at the South African National Championships. Performance assessment in the laboratory was done in January after the Christmas holidays and base training period, and the week after the National Championships in March, 2004.
2. Periodised Planning of Training: A basic layout of time spent in each heart rate zone based on a maximal amount of 15 hours per week was given to CS3.
3. Feedback on Training: The training log was still used as part of the feedback, but heart rate data was the primary source of feedback. The training data was downloaded at least once a month, but if the watch was full data was downloaded earlier.
4. Training Sessions: The training modes available to CS3 were, road cycling, roller trainers, track cycling and gymnasium work. He started training with a coach.
5. Training Camps: An assessment by a physiotherapist involved in persons with cerebral palsy was done, to improve aspects regarding bicycle set-up and daily living to enhance performance.
6. Sports Medicine services and products: No funding.

Physiological Evaluations

The first assessment was completed in January, just after a long period of base training which included Christmas holidays. The second assessment was completed after the South African National Championships for the Physically Disabled in March, 2004. The first testing was therefore not at a peak time, but the second was. The results from testing in October, 2003 (same as reported in First Macrocycle) were used to compare with the peak period of March, 2004.

Anthropometry

Table 59 is a summary of the anthropometric measurements for CS3 during the Second Macrocycle.

Table 59. Anthropometric measurements of CS3 (Second Macrocycle)

Date	October 2003	January 2004	March 2004
Age (yrs)	20	20	20
Body mass (kg)	63.7	64.4	64.7
Height (cm)	170.5	170.6	170.5
% Fat	7.2	9.5	8.2
Somatotype	1.5 – 5.5 – 2.7	1.8 -5.8 -2.6	1.9 – 5.6 – 2.5

Body mass CS3's body mass changed from October to January with 0.7 kg. A further increase of 0.3 kg in body mass is visible from January to March.

Height Only a 0.1 mm difference between October and January and January and March.

Fat percentage The measurement of fat percentage indicated changed of 2.3 % from October to January, but this is not consistent with the smaller change in body mass and is likely due to the variability in measurement of skinfolds..

Somatotype His somatotype indicates a change in the mesomorphic and endomorphic components from October to January, with a decrease in the mesomorphic component towards March.

General His fat percentage changed a bit from October to January, but decreased again towards competition time.

Incremental Exercise Test to Exhaustion.

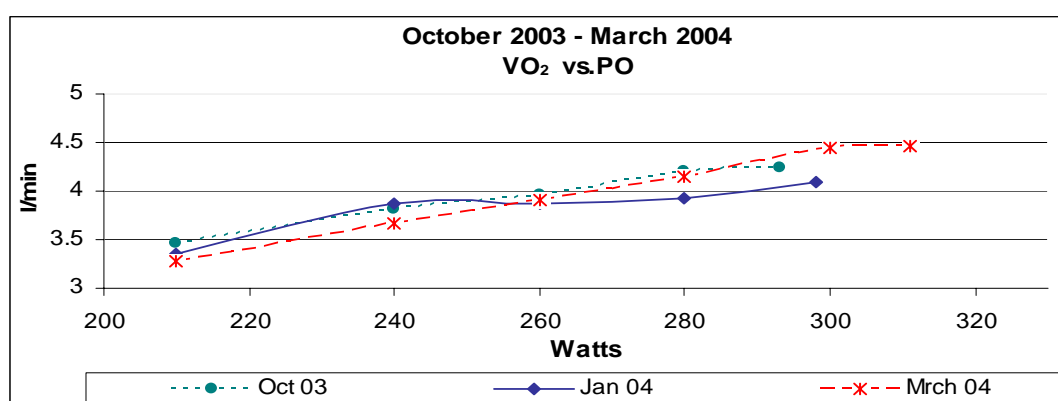
The results of this test are presented in Table 60.

Table 60. Results of the incremental exercise test to exhaustion for CS3 (Second Macrocycle)

	October 2003	January 2004	March 2004
Total time of test (min:s)	11:44	12:19	13:55
VO ₂ max (l/min)	4.24	4.09	4.46
VO ₂ max (ml/kg/min)	66.7	63.5	69
HR _{max} (bpm)	210	211	210
Peak power (PPO) (Watts)	293	298	311
Peak power: weight (W/kg)	4.61	4.63	4.80
Max lactate (mmol/l)	11.2	15.2	7.3
La ₂ (Watts)	Start	Start	117
La ₂ (HR)	129	121	157
La ₄ (Watts)	225	173	260
La ₄ (HR)	184	173	191
RER	1.07	1.08	1.06
RER of 1 (Watts)	240	261	276
RER of 1 (HR)	191	196	196
Time cycled at RER above 1 (min:s)	6:44	4:21	4:45

Graph 122 illustration of the efficiency of pedaling expressed as the relationship between oxygen used and work done (watts of pedaling).

Graph 122. Pedaling efficiency for CS3 (Second Macrocycle)



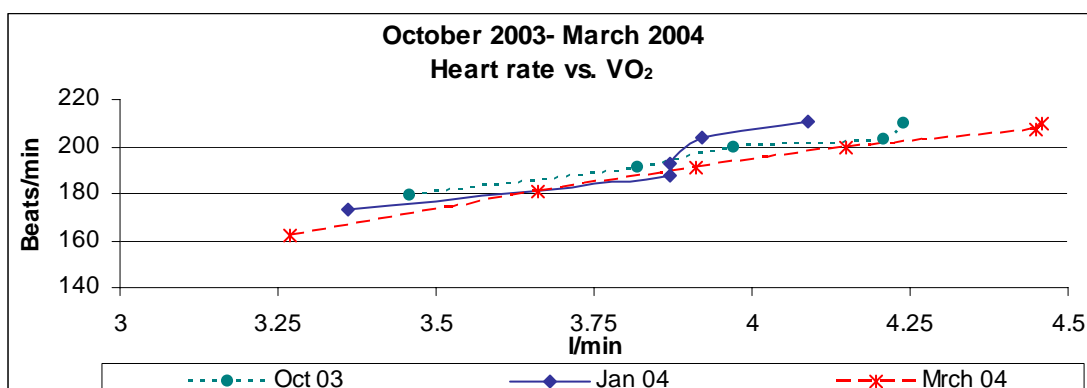
The maximal oxygen uptake is the body's capacity to transport and utilize oxygen during exercise (Powers & Howley, 2001).

- The October plot is the same that was used during the First Macrocycle.

- The January testing showed a slight plateau in VO_2 between 240 and 280 Watts. This indicates that pedaling efficiency actually improved so that more work could be done at 280 Watts for the same oxygen cost. After 260 Watts, the January pedaling efficiency was better than October or March. A maximum after a peak was reached at 260 Watts. A decrease of 4.7 % in VO_2max (l/min) was seen, despite a 1.7 % change in PPO.
- March data indicated a 5 % increase in VO_2max (l/min) and a 3.4 % increase in relative VO_2max (ml/kg/min). PPO increased with 6.1 % since October 2003. The pedaling efficiency for March improved at the workloads lower than 260 Watts.

Graph 123 illustrates the heart rate per oxygen uptake (VO_2).

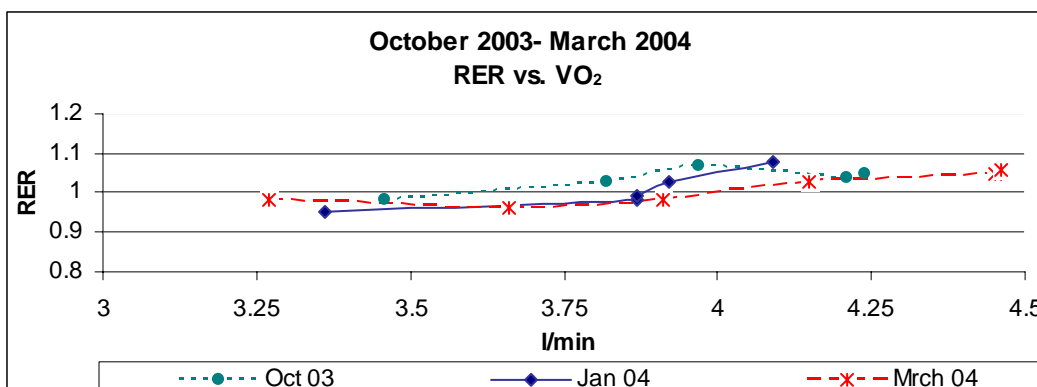
Graph 123. Heart rate for CS3 (Second Macrocycle)



- A linear graph in January is only visible until the value of 3.78 l/min was achieved. After that his HR cost for VO_2 increased but not linearly, till a maximum heart rate of 211 bpm.
- The March testing indicated the most improved heart rate efficiency of all three tests. A maximum heart rate of 210 bpm was achieved. At all workloads his heart rate was lower than any of the other two tests.

Graph 124 presents the relationship between the respiratory exchange rate (RER) and oxygen uptake (VO_2). RER indicates the estimated percentage contribution of carbohydrate or fat to energy metabolism during exercise. It is the ratio of carbon dioxide output (VCO_2) to the volume of oxygen consumed (VO_2) (Powers & Howley, 2001).

Graph 124. Respiratory exchange rate for CS3 (Second Macrocycle)

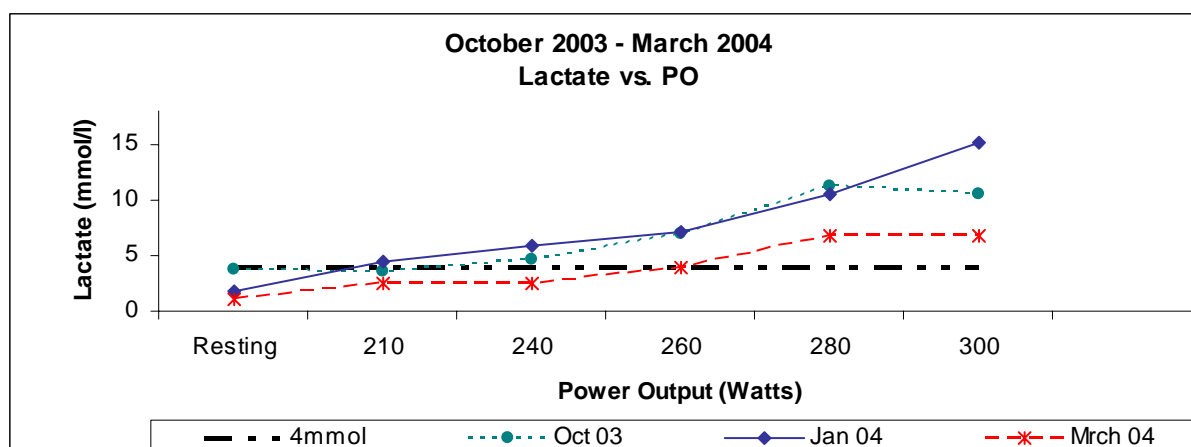


A RER under 1 indicates a desirable level in CS3's capacity to use the oxidative system to produce energy for the cycling action. A lower RER indicates greater fat vs. carbohydrate oxidation. In contrast, a RER above 1 indicates hyperventilation associated with anaerobic metabolism and fatigue.

- During the October testing, a maximum RER of 1.05 was found. The first workload was the only workload CS3 was able to cycle under a RER of 1. This indicates that his fat metabolism needs to improve to enable him to save the carbohydrate stores for higher intensity work. Although a RER of 1 was reached at a low workload, it still represents 90 % of his VO₂max.
- In January, a RER of 1 was reached at 95 % of VO₂max achieved in January and at 88 % of PPO.
- March data indicated that CS3 was the most adapted towards aerobic metabolism of the three tests. RER of 1 was reached at a higher VO₂ in March and he could last longer so his peak PPO and VO₂max also improved.

Graph 125 is an illustration of blood lactate concentrations (mmol/l) at each workload (Watts) during the incremental test.

Graph 125. Blood lactate accumulation for CS3 (Second Macrocycle)



- OBLA was achieved at 77% of PPO (225 Watts) during October.
- OBLA was achieved at 58 % of PPO (173 Watts) in January.
- OBLA was achieved at 84 % of PPO (260 Watts) in March.

This is an indication that although PPO increased in March, the endurance training was sufficient to increase power output at OBLA to the same percentage of maximum PPO. The Watts at which OBLA was achieved increased from October to March with 15.5 %, despite a decrease in OBLA in between in January.

Wingate Test (sprint power and resistance to fatigue)

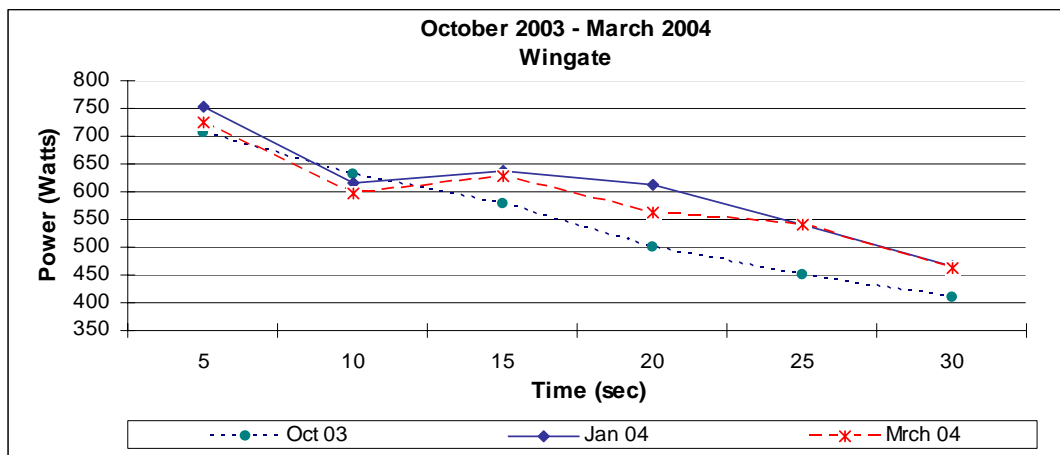
Results of the 30 second Wingate test are presented in Table 61.

Table 61. Values obtained during the 30 second Wingate test for CS3 (Second Macrocycle)

	October 2003	January 2004	March 2004
Resistance	9.8 % / BW	9.8 % / BW	9.8 % / BW
Body mass (kg)	63.7	64.4	64.7
Peak sprint power (Watts)	706	752	724
Relative peak sprint power (W/kg)	11.1	11.7	11.2
Avg sprint power (Watts)	546	605	586
Relative avg sprint power (W/kg)	8.6	9.4	9.1
Minimum sprint power (Watts)	409	466	462
Avg sprint power / peak sprint power (%)	77%	80%	81%
Fatigue index (W/s/kg)	0.16	0.15	0.14

Graph 126 is an indication of the average power output (Watts) during each 5 seconds of the Wingate test.

Graph 126. Sprint power and resistance to fatigue for CS3 (Second Macrocycle)



- In October, CS3 had a sharp negative change from peak to minimum sprint power, which indicates a lack of muscular endurance at high intensity.
- CS3's best peak and mean sprint power (752 & 605 Watts) was achieved in January. This was a 6.5 % and 9.7 % increase since October in peak and mean sprint power respectively.
- A slight change in peak and mean sprint power was seen from January to March, but the March results are still higher than in competition time in October 2003.

1-Hour Distance Trial

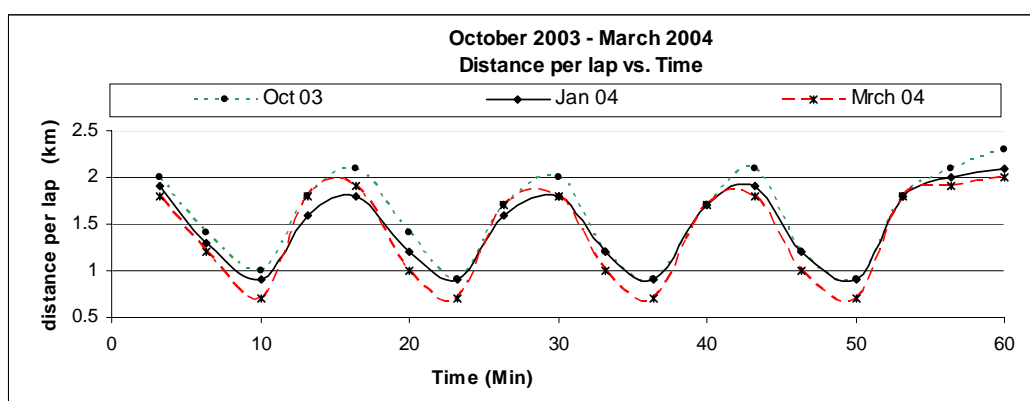
The results of this test are presented in Table 62.

Table 62. Values obtained during 1-hour distance trial for CS3 (Second Macrocycle)

	October 2003	January 2004	March 2004
Total distance (km)	34.5	30.6	28.9
Ave cadence (rpm)	79±10	81±14	67±13
Total distance 4% incline (km)	7.2	5.6	5.1
Avg cadence 4% incline (rpm)	73±10	79±10	72±11
Total distance 8% incline (km)	4.9	3.2	2.9
Avg cadence 8 % incline (rpm)	68±2	62±5	55±1
Avg heart rate (bpm)	182±15	185±7	183±8
Highest heart rate (bpm)	206	189	194

Total Distance. Graph 127 illustrates the distance for each split over time. For interpretation of the graph remember from the method section that each lap represent 3 minutes and 20 seconds. To simplify the interpretation of the graph, it should be remembered that the first lap was a flat distance, the second a 4 % gradient hill, the third lap an 8 % gradient hill, followed by two flat laps, before the first 4 % gradient commenced again and the sequence was repeated four times. The last 10 minutes were flat. The peak distances were during the flat part of the test and the shorter distances during the climbs.

Graph 127. Lap distance (km) during 1-hour distance trial for CS3 (Second Macrocycle)

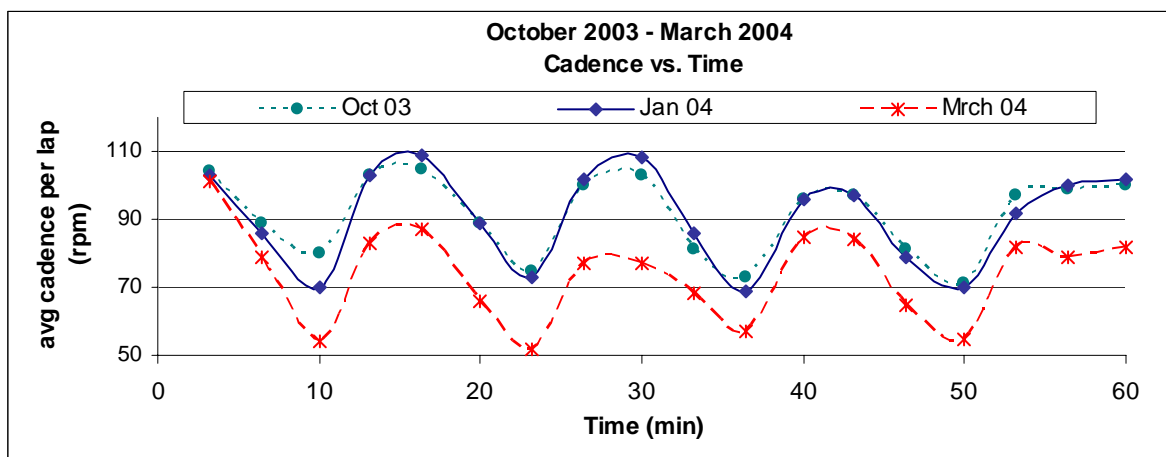


(Rationale for connecting the data points was presented in Chapter Three.)

- The distance covered in October was the highest over the flats, 4 % gradient hill and the 8 % gradient hill. October shows a good final effort over the last 10 minutes.
- During January the distance covered decreased by 3.9 km, with decreases on the 4% hill (-5.6 km) and on the 8% hill (-3.2 km). In total, the change in distance on the hills was much more than on the flats (-0.6 km).
- The total distance covered during March show a 16.2 % decrease in distance since October (34.5 km). A 4.1 km difference in distance covered on the hills is responsible for 73 % of the total difference in distance covered.

Cadence (rpm). Graph 128 is an illustration of the cadence (rpm) averaged for each lap over the period of time. The cadence was higher on the flat part of the race and lower on the hills.

Graph 128. Cadence (rpm) selection during the 1-hour distance trial for CS3 (Second Macrocycle)



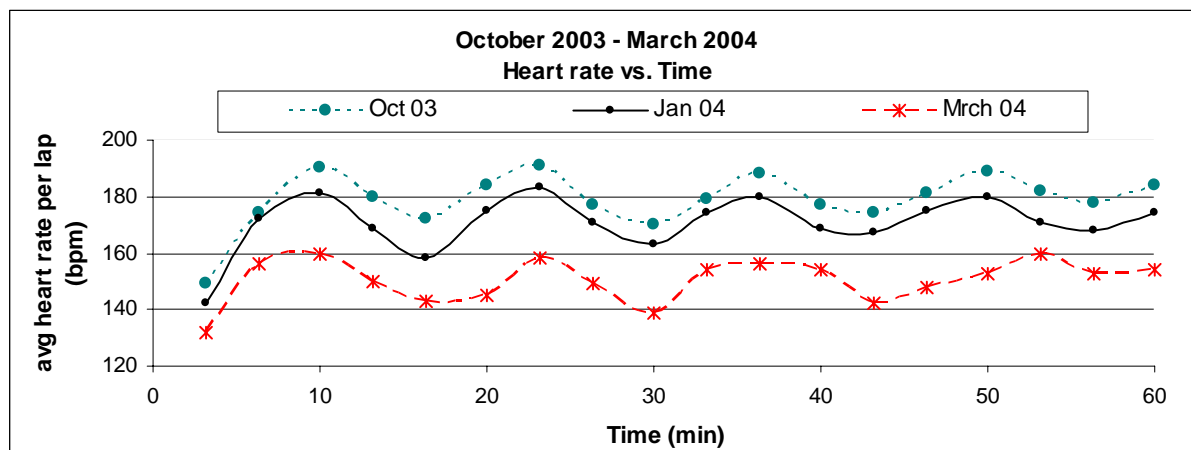
(Rationale for connecting the data points was presented in Chapter Three.)

The graph above indicates that CS3 had a similar cadence selection during October and January, but quite different in March.

- The main difference between October and January was a decreased cadence especially the 8 % gradient hill, from 68 – 62 rpm. Although the average cadence is only 2 rpm different from October, the cadence on the 4 % hill was 6 rpm faster, and on the 8 % hill 6 rpm slower.
- The average cadence for March was only 68rpm, with a cadence of 72 rpm on the 4 % gradient hill and 55 rpm on the 8 % gradient hill. This indicates a decrease in average cadence on the flats and both hills.

Heart Rate (bpm). Graph 129 illustrates the heart rate (beats/minute) averaged for each lap over the time period of the test.

Graph 129. Heart rate (bpm) during 1-hour distance trial for CS3 (Second Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

The incremental exercise tests indicated that CS3's maximum heart rate was 211 bpm. This was taken as HR_{max} for calculations.

- In October, CS3 averaged at 86% of HR_{max} and 99 % of HR_{OBLA} achieved in October.
- In January, CS3 averaged at 88 % of HR_{max} , and 107 % of HR_{OBLA} achieved in January.
- CS3 averaged at 87 % of HR_{max} and 96 % of HR_{OBLA} achieved in March.

The percentage of HR_{max} indicates that the effort according to HR_{max} was the within a 2 % range for the three tests. HR_{OBLA} ranged much more between 96 – 107 % of HR_{OBLA} .

Summary of 1-Hour Distance Trial. CS3 had a decrease in distance covered during the 1-hour distance trial over the macrocycle therefore the performance was worse. This was not due to a decrease in physiological intensity of effort as judged from heart rate which stayed the same. Rather the poorer performance might have been related to cadence which decreased with the decreased distance, especially on the hills.

1 km Time Trial

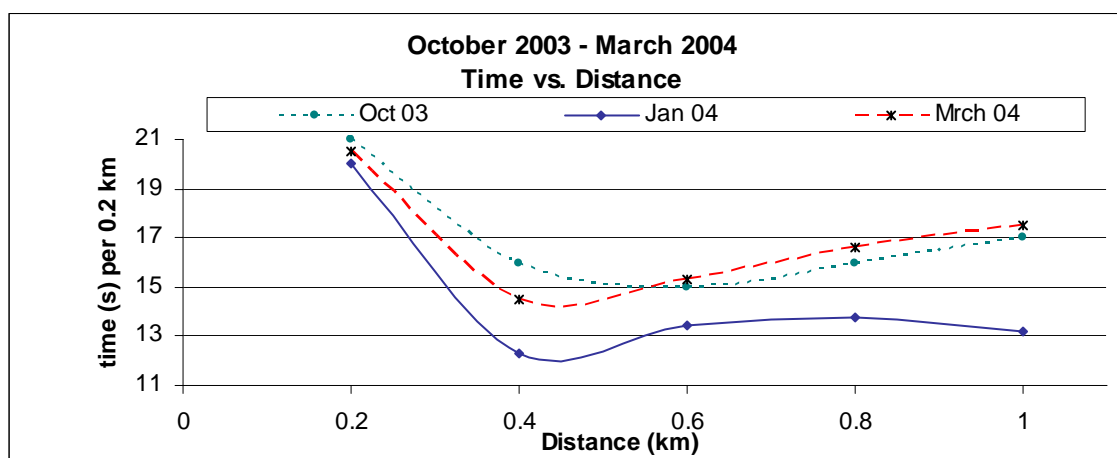
Results of the 1 km time trial are presented in Table 63.

Table 63. Results during the 1 km time trial for CS3 (Second Macrocycle)

	October 2003	January 2004	March 2004
Gear selection	90	88	90
Time (min:s)	1:20.6	1:12.7	1:24.4
Avg cadence (rpm)	Faulty equipment	126±7	111±7
Avg speed (km/h)	44.7±7	49.5±7	42.65±4
Avg heart rate (bpm)	187±17	178±31	182±25
Highest heart rate (bpm)	199	199	196

Time / Distance. Graph 130 illustrates the time taken (s) for each 0.2 km during the 1 km time trial for CS3 (Second Macrocycle).

Graph 130. Time taken (s) for each 0.2 km during the 1 km time trial for CS3 (Second Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

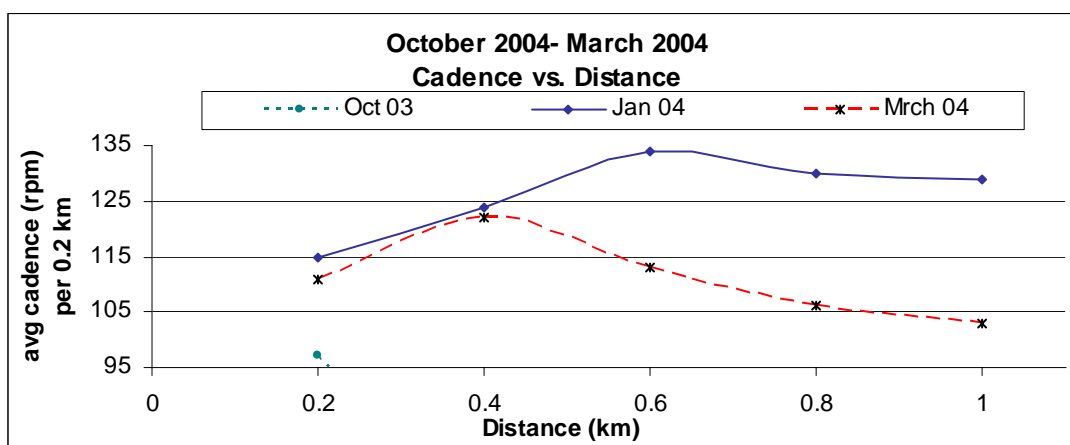
This graph is an indication of the 1 km track time trial capacity of CS3 and the tactics he used.

- In October, the start over the first 0.4 km was the slowest of all three tests with the peak speed achieved between 0.4 km and 0.6 km, from where it decreased again.

- January data indicated the fastest starting and maximum speed as well as the best speed maintenance.
- March data indicated a faster start than in October and a greater maximum speed between 0.2 km and 0.4 km but a negative change in speed after maximum speed was obtained. This resulted in an average speed of 42.7 km/h.

Cadence (rpm). Graph 131 illustrates the cadence averaged for each 0.2 km during the 1 km time trial.

Graph 131. Cadence (rpm) selection during 1 km time trial for CS3 (Second Macrocycle)



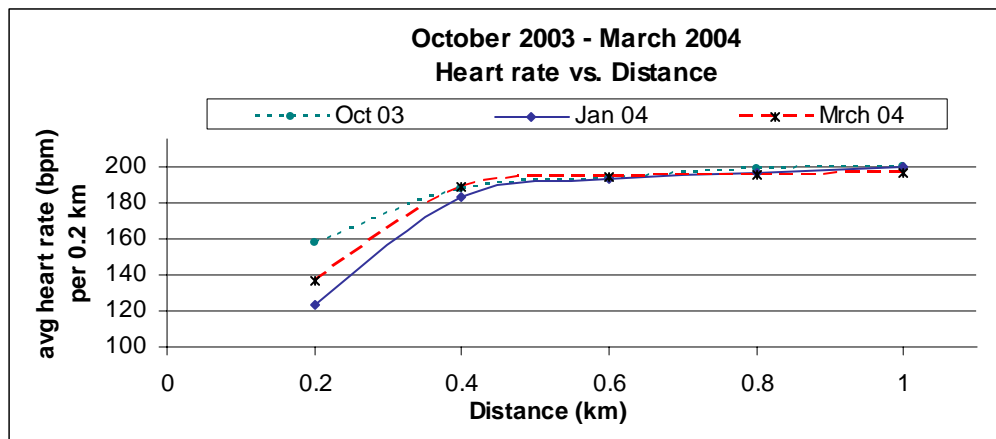
(Rationale for connecting the data points was presented in Chapter Three.)

The fact that no gear change is possible on a track bike, the gear selection is important when consider the cadence used. During the October and March trials the gear selection was 90 and during January it was an 88.

- Faulty equipment in October resulted in no cadence being measured.
- January data indicated a change of cadence to a maximum at between 0.4 km and 0.6km with an average cadence of above 130 rpm. The cadence then changed negatively but an average cadence of 126 rpm was still maintained.
- Over the first 0.4 km, the cadence for March was close to that of January, after which a negative change in cadence is visible. This indicated an inability to sustain the cadence and therefore indirectly a lack in muscular endurance to sustain the power output that the 90 gear required during the 1 km distance.

Heart Rate (bpm). Graph 132 illustrates the heart rate (bpm) averaged for each 0.2 km over the distance (km) covered.

Graph 132. Heart rate (bpm) during 1 km time trial for CS3 (Second Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

- The average heart rate during October was much higher than during January or March over the 1 km, because of a quicker early response.
- The January average heart rate was 9 bpm lower although the highest HR was similar. The difference in heart rate between October and March is found during the first 0.6 km. It seemed that the bigger gear resulted in a higher average heart rate especially over the first part of the time trial.
- March indicated an average heart rate of 182 bpm, and 196 rpm.

Summary of 1 km Time Trial. The main difference in the 1 km time trial, is the capacity to maintain the speed and therefore muscle or speed endurance (Friel, 2003). This was seen as the ability of CS3 to maintain cadence with the smaller 88 gear and achieving an average speed of 49.5 km/h over the 1 km. The determination of the gear seems to play an important role in performance and further investigation is necessary.

3 km Time Trial

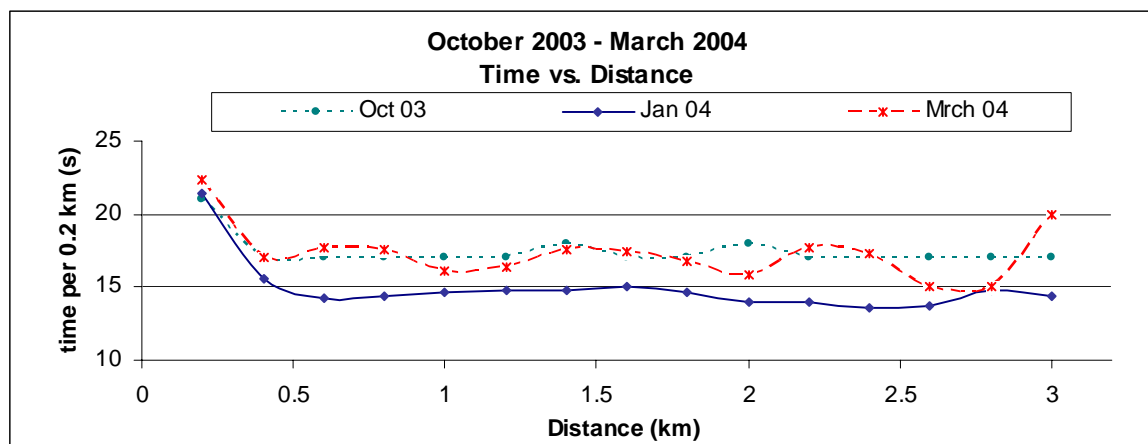
Results of the 3 km time trial are presented in Table 64.

Table 64. Results during the 3 km time trial for CS3 (Second Macrocycle)

	October 2003	January 2004	March 2004
Gear selection	90	88	90
Time (min:s)	4:21	3:44	4:19.9
Avg cadence (rpm)	104±1.6	120±7.5	104±2.5
Avg speed (km/h)	41.4±2.4	48.2±4.2	41.7±2.6
Avg heart rate (bpm)	188±11.4	188±17	188±18
Highest heart rate (bpm)	201	201	204

Time / Distance. Graph 133 illustrates the time taken (s) for each 0.2 km during the 3 km time trial.

Graph 133. Time taken (s) for each 0.2 km during 3 km time trial for CS3 (Second Macrocycle)



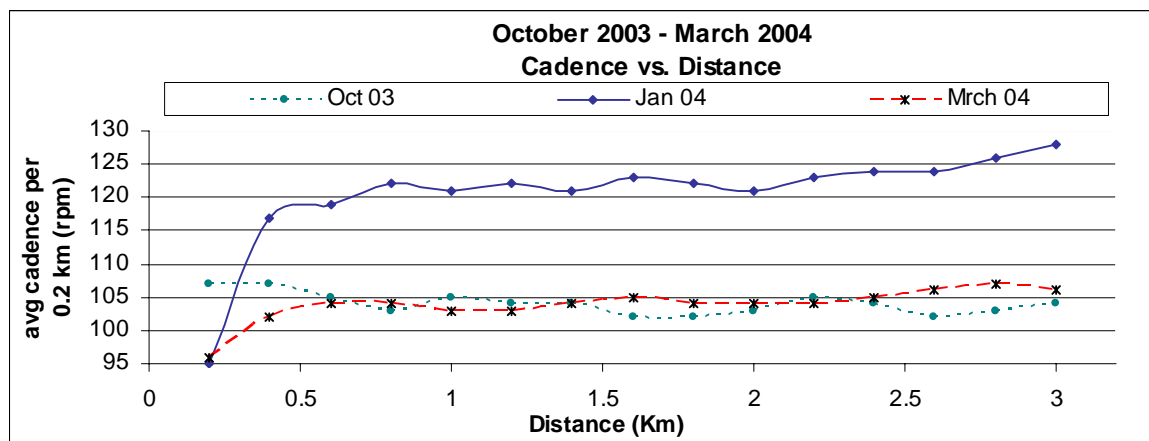
(Rationale for connecting the data points was presented in Chapter Three.)

This graph is an indication of the riding capacity during the 3 km track pursuit as well as the tactics used during the test.

- October and March were similar during the Second Macrocycle.
- January data indicated the fastest speed of 48.2 km/hr. This is only 3 % slower than his average speed in the 1 km time trial. CS3 reached a maximum speed where he cycled faster than 15 seconds per 0.2 km after 0.6 km, for the rest of the test.

Cadence (rpm). Graph 134 illustrates the cadence (rpm) averaged for each 0.2 km during the 3 km time trial.

Graph 134. Cadence (rpm) selection during 3 km time trial for CS3 (Second Macrocycle)



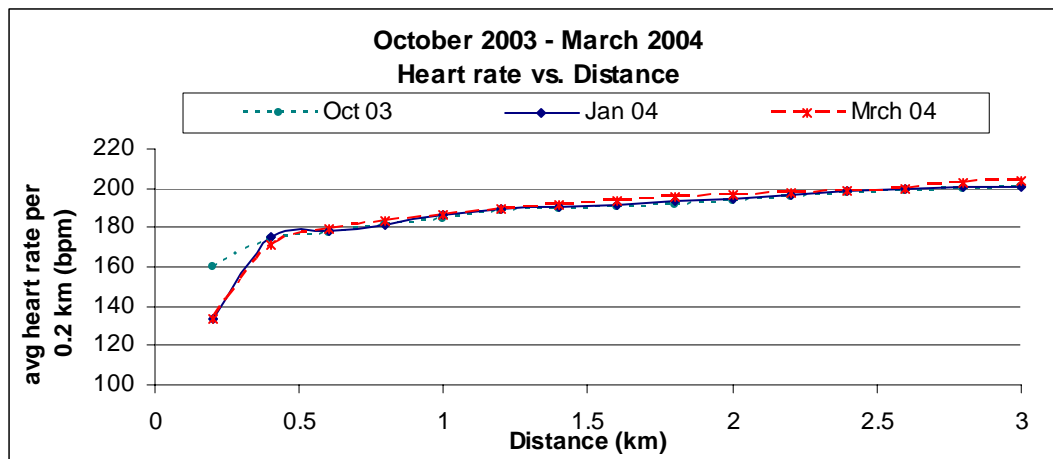
(Rationale for connecting the data points was presented in Chapter Three.)

The fact that no gear change is possible on a track bike, the gear selection is important when considering the cadence used. During October and March the gear selection was 90, with a gear of 88 in January.

- October data indicated a cadence of above 105 rpm for the first 0.4 km whereafter it decreased to between 100 – 105 rpm. An average cadence of ± 103 rpm was achieved.
- January data indicated a high average cadence of 120 rpm. His cadence started off slow, with a gradual increase in cadence until the end of the time trial. Over the first 0.4 km a steep increase in cadence is visible. The cadence was then maintained between 120-125 rpm, with an increase in cadence over the last 0.2 km of above 125 rpm.
- March data indicated as for October, an average cadence of 104 rpm, just with different tactics. In March he started off slowly, with an increase in cadence over the last 0.2 km of the race. During October it was a fast start and a decrease in cadence towards the end.

Heart Rate (bpm). Graph 135 illustrated the heart rate (bpm) averaged over each 0.2 km over the distance (km) covered.

Graph 135. Heart rate (bpm) during 3 km time trial for CS3 (Second Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

- The average heart rate for the different laps for all three trials was similar, with only March having a higher highest heart rate of 204 bpm.

Summary of 3 km Time Trial. The interesting fact for the 3 km time trial was that the fastest time was achieved in January. He did a lot of base training in the time period before the testing. January also indicated the highest cadence. The smaller gear allowed a faster cadence and less intensity for the fast twitch muscle fibers (Takaishi et al., 1996) due to the lower power required at a fast cadence. But it did require for higher muscular endurance at a lower intensity.

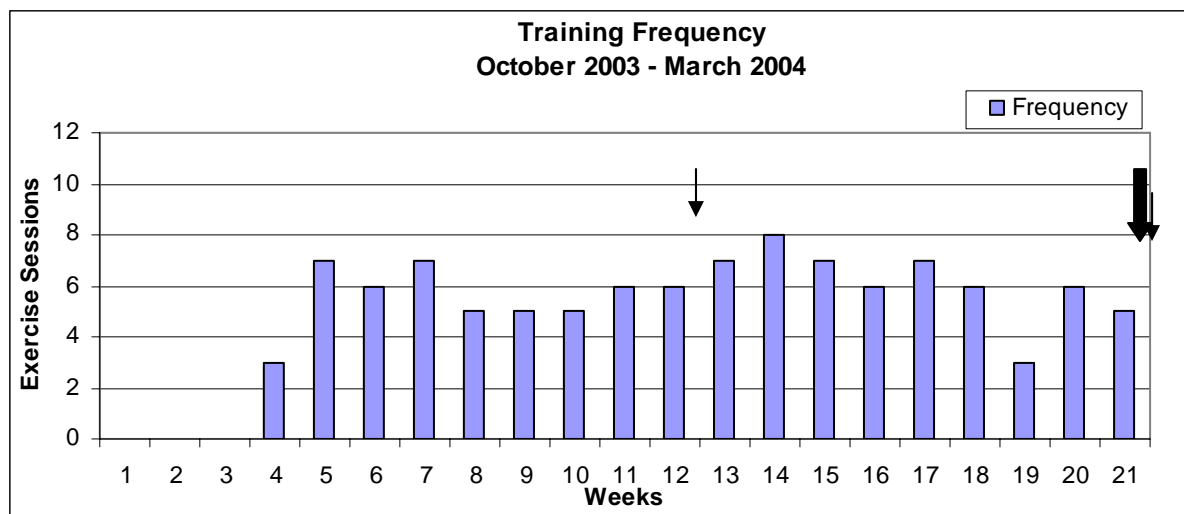
Training

During the Second Macrocycle, the training logs and heart rate monitor data of CS3 were used to determine his training intensity, volume, frequency and the mode of training.

Training Frequency

Graph 136 illustrates the exercise sessions per week for the Second Macrocycle.

Graph 136. Training frequency for CS3 (Second Macrocycle)



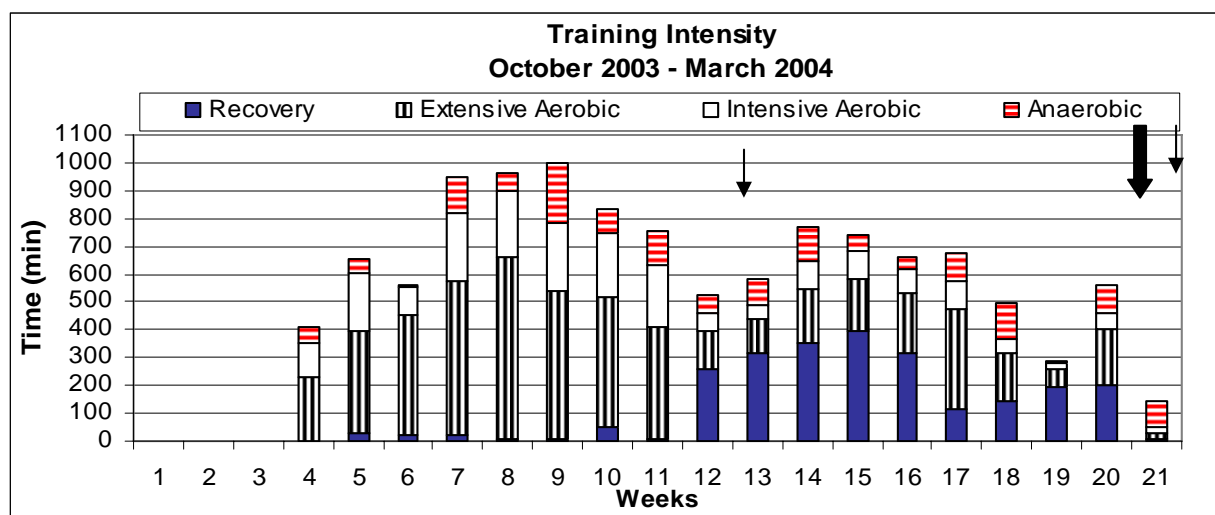
↓ Indicative of the competition times. ↓ Indicative of testing times.

CS3 did not train during the first 3 weeks of the second macro cycle. During this time he was busy with his year end exams and took a complete break of cycling to focus on his studies. From weeks 7-12 he trained on average ± 6 times a week. Weeks 13 – 18 showed an increase in training frequency to ± 7 sessions per week. A decrease in training was seen in Week 19 to three training sessions for the week.

Training Intensity

Graph 137 is an illustration of the average heart rate training intensities during each week.

Graph 137. Training intensity for CS3 (Second Macrocycle)



↓ Indicative of the competition times. ↓ Indicative of testing times.

Table 65. Percentage of training time in each training zone for CS3 (Second Macrocycle)

Weeks	Recovery Zone (<70%)	Extensive Endurance (70-80%)	Intensive Endurance (80-85%)	Anaerobic (>85%)
1- 6	3.1% (50 min)	63.5% (1033 min)	25.9 % (422min)	7.5 % (123 min)
7-12	7.1 % (355 min)	54.5 % (2743 min)	24.8 % (1248 min)	13.6 % (686 min)
13-18	41.7 % (1635 min)	32.1% (1256 min)	12.6 % (949 min)	13.6 % (494 min)
19-20	40.5 % (995 min)	28.7% (265 min)	10.9% (108 min)	19.9 % (108 min)

Data presented in this graph are only heart rate data gathered using the heart rate monitor. During the first six weeks of the macrocycle, training was supposed to focus was on long sustained rides to build a base for future high intensity training. This is supported by 64 % of training spent in the extensive endurance zone and only 7.5 % of his training above 85 % of heart rate max. During the second six weeks it was expected that the percentage of training should still focus the most on the extensive endurance zone, with increased percentages in the intensive and anaerobic zones, which CS3 did. He still spent 55 % of his training in the extensive endurance zone, but time in the anaerobic zone

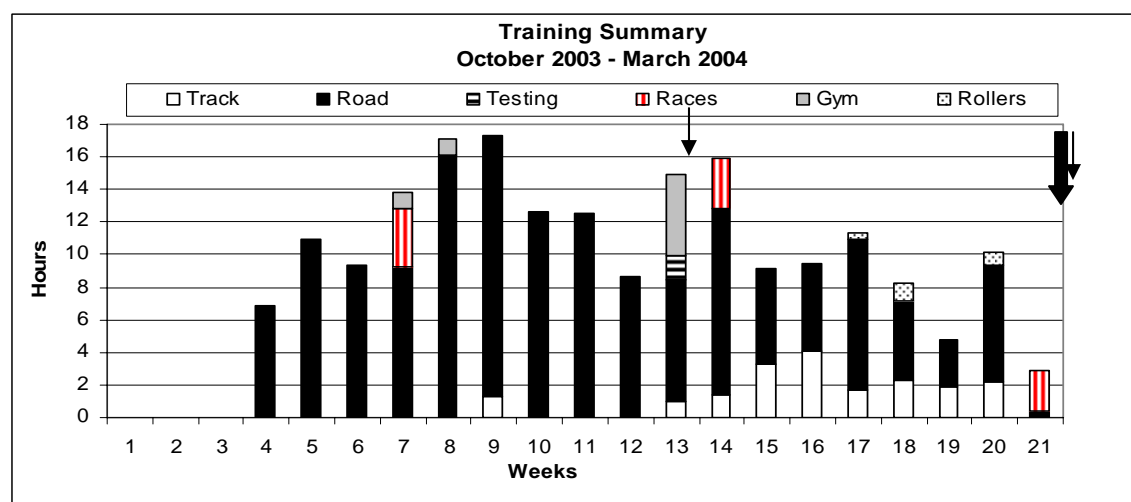
increased to 14 %. During weeks 13-18 where the intensity of training should be the highest, his heart rate data indicates a lot of training time spent in the recovery zone (heart rate lower than 70 % of HR_{max}). The training time on the track increased and the time in the recovery zone might have increased due to the rest time between interval training on the track. His time in the recovery zone should still not be this high. The same heart rate splits are seen in weeks 19- 21, which is the tapering and competition weeks. This might be an area that CS3 needs to look at to improve performance. The great amount of “easy” training might lead to early detraining and not peaking.

Training Volume and Training Modes

CS3 noted the different training modes he used to do his training in his training log as well as on an electronic training diary (Polar Precision Software).

Graph 138 illustrates the different training modalities used during the Second Macrocycle.

Graph 138. Training summary for CS3 (Second Macrocycle)



Indicative of the competition times.



Indicative of testing times.

The training summary is an indication of the different training modes that CS3 used to train. CS3’s main training modes were road training, track training and roller training. During the 1st and 2nd mesocycles in Macrocycle Two CS3 spent 100 % and 92 % respectively of his training on the road. This decreased to 64 % and 59 % of his training during weeks 13- 18 and 19 – 21. This indicated the increase in track training from no

training on the track during weeks 1-6 and 7-12, to 20 % and 23 % of training on the track during Weeks 13- 18 and Weeks 19 -21, respectively. This indicated a good specificity due to the fact that track training is important to improve performance on the track. During the first two mesocycles, the importance given to track training was not as great due to the fact that time spent on the bicycle as well as long endurance rides are important to build a base for the higher intensity training. The fact that CS3 needed to compete in both, makes it important to combine these two training modes as best possible. Roller training formed part of his training but only when necessary and never took up more than 4 % of total training time.

General Summary of Training

During the Second Macrocycle the main focus was to build a good base. Holidays made it possible to spend more time training especially during weeks 7 -12. CS3 shows a good periodised plan according to time spent in training zones, increase in volume as well as the training mode during the first 12 weeks. Thereafter CS3 shows a lack of high intensity training, and a great percentage of training was conducted in the recovery zone. This is the same time as when track training was incorporated into the training and it might be part of the reason for the increased recovery time. The specificity of training regarding track or road is good, the unknown fact is how specific was the training sessions in reaching certain goals? A definite area to improve is to combine the track and road sessions to let both racing modes benefit.

Direct Factors Targeted during Second Macrocycle

The research question guiding this study focused on the management of selected direct factors important for sport performance management. The following rating scale reflects the investigator's perceptions of the degree of success in managing these factors.

Direct Factor	Score	Reasons
Performance Assessment	4	The main goal for the competition was to qualify for the Paralympic Games. The goal was achieved by being included in the training squad. The laboratory tests were all conducted with motivation. The results need to be studied closer to evaluate why CS3 performed at his best in the time trials in January, rather than at competition times.
Periodised Planning of Training	2	An improvement in the first 12 weeks of training was seen. Training intensities were on target, and the training volume of maximum training hours per week of 15 hr were nearly achieved between weeks 7-12, with an average of 13.6 hr per week for that time period. His training intensities then decreased instead of increasing, and a drop in training volume is visible. Instead of combining the drop in volume with high intensity to get a desirable training load, both dropped. This might have led to detraining towards competition time.
Feedback on Training	4	His feedback on training was mostly received through email and the Precision Performance Software was used to analyze it. At least every two weeks, except in holiday times, training was received.
Training Sessions	3	No specific feedback on training sessions was received. Regarding the training modes, he did include track training at a good time into his training. A problem is that he has two different coaches that do not communicate on the common goals.
Training Camp	4	The only area for concern for the physiotherapist was CS3's lack of use of his cerebral palsy arm and hand.
Sports Medicine Services & Products	5	No specific sports medicine support due to lack of funding.

Score = Point out of 5, with 0 not achieved, 5 fully achieved.

Physiological Monitoring Third Macrocycle: March, 2004 – October, 2004

The Third Macrocycle was set after the transition phase following the South African National Championships for the Physically Disabled held in April, 2004, until the Paralympic Games, Athens, 2004.

Goals for the Third Macrocycle

The goals for the Third Macrocycle were personal best performances at the Paralympic Games. This can be done by improving leg power as well as his aerobic capacity.

Direct Factors Targeted during the Third Macrocycle

The research question guiding this study focused on the management of selected direct factors important for sport performance for elite cyclists with cerebral palsy. The following direct factors were identified:

1. Performance Assessment: The main focus for this cycle was to compete at maximum capacity at the Paralympic Games.
2. Periodised Planning of Training: A basic layout of training was given to CS3.
3. Feedback on Training: Training logs and heart rate monitor feedback was given to the investigator at least once a month, or when possible earlier.
4. Training Sessions: The training modes available to CS3 were road cycling, roller trainers, track cycling. Detailed planning of the training sessions was done by CS3's coach.
5. Training Camps: CS3 attended a two week residential training camp at Stellenbosch University.
6. Sports Medicine services and products: Funding available for needs.

Physiological Evaluations

The first assessment was completed in June, 2004, just after the base training phase. The second assessment was six weeks later in July, after the two-week Paralympic Team training camp. The third assessment was conducted in October, within two weeks following the Paralympic Games.

Anthropometry

Table 66 is a summary of the anthropometric measurements for CS3 during the Third Macrocycle.

Table 66. Anthropometric measurements of CS3 (Third Macrocycle)

Date	March 2004	July 2004	October 2004
Age (yrs)	20	21	21
Body mass (kg)	64.7	65.1	66.7
Height (cm)	170.5	170.5	170.5
% Fat	8.2	8.9	9.9
Somatotype	1.9 – 5.6 – 2.5	1.9 – 6.2 – 2.2	2.2 – 5.8 – 2.3

Body mass CS3's body mass changed with 0.4 kg, from March to July, with a further increase of 1.6 kg towards October. This results in a 3 % change in body mass from March to October, but whether or not this occurred after he competed cannot be assessed.

Height No difference in height.

Fat percentage His percentage body fat changed with 0.7 % from March to July, with a further 1 % change in body fat towards October.

Somatotype An increase in the mesomorphic component from March to July is visible, but it negatively changed again towards October, with an increase in the endomorphic component.

General The increase in the mesomorphic component as well as the increase in body fat percentage indicates that the increase in body mass in July is due to an increase in muscle mass as well as fat percentage which is not ideal.

Incremental Exercise Test to Exhaustion

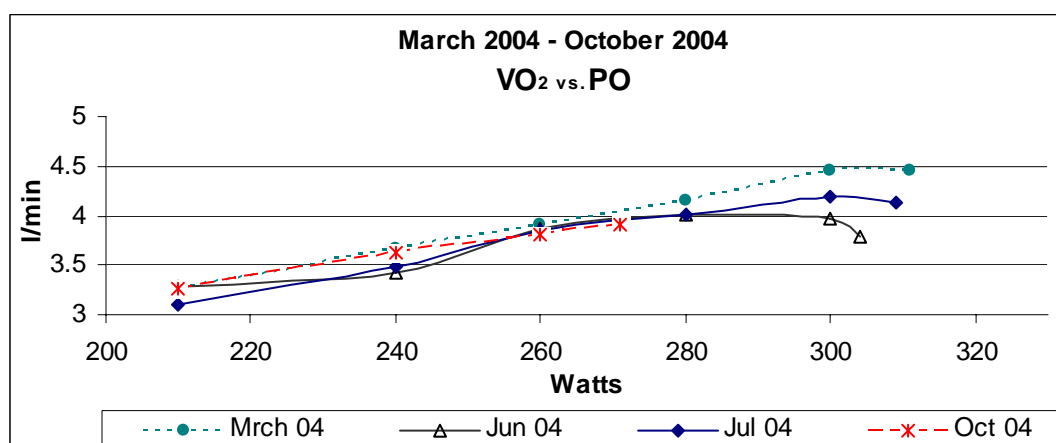
The results of this test are presented in Table 67.

Table 67. Results of the incremental exercise test to exhaustion for CS3 (Third Macrocycle)

	March 2004	June 2004	July 2004	October 2004
Total time of test (min:s)	13:55	13:19	13:43	8:51
VO ₂ max (l/min)	4.46	4.22	4.20	3.90
VO ₂ max (ml/kg/min)	69	65.3	64.1	58.5
HR _{max} (bpm)	210	200	211	189
Peak power (PPO) (Watts)	311	304	309	271
Peak power: weight (W/kg)	4.8	4.70	4.71	4.06
Max lactate (mmol/l)	7.3	7.3	11.7	6.7
La ₂ (Watts)	117	130	90	Start
La ₂ (HR)	157	160	164	120
La ₄ (Watts)	260	263	234	214
La ₄ (HR)	191	187	193	169
RER	1.06	1.00	1.10	1.02
RER of 1 (Watts)	276	304	248	260
RER of 1 (HR)	196	200	187	187
Time cycled at RER above 1 (min:s)	4:4`5	13:00	7:43	1:21

Graph 139 illustration of the efficiency of pedaling expressed as the relationship between oxygen used and work done (watts of pedaling).

Graph 139. Pedaling efficiency for CS3 (Third Macrocycle)

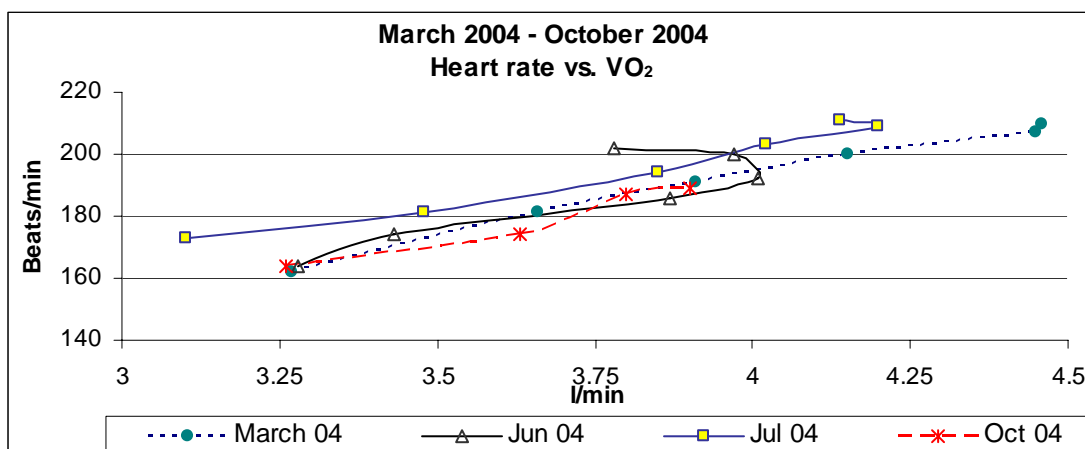


- The March plot is the same that was used during the Second Macrocycle.

- The June plot indicated an improved pedaling efficiency with lower VO_2 at most workload. The VO_2 max decreased to 4.22 l/min or 65.3 ml/kg/min, although PPO only decreased with 2 %. If taken into account that this was base training, the peak values were well maintained.
- No real difference was noticed between June and July. This may be because CS3 did not participate fully in the training camp.
- The October plot indicated a poor test. CS3 was tested twice during this phase, due to a lack of maximal values obtained. The results being the same after both tests. Lack of motivation might be a factor, although CS3 said that he gave his best and he could not cycle any further. Taken together with the higher lactate values, these data seemed to indicate that CS3 had detrained prior to this test.

Graph 140 illustrates the heart rate per maximal oxygen uptake (VO_2).

Graph 140. Heart rate for CS3 (Third Macrocycle)

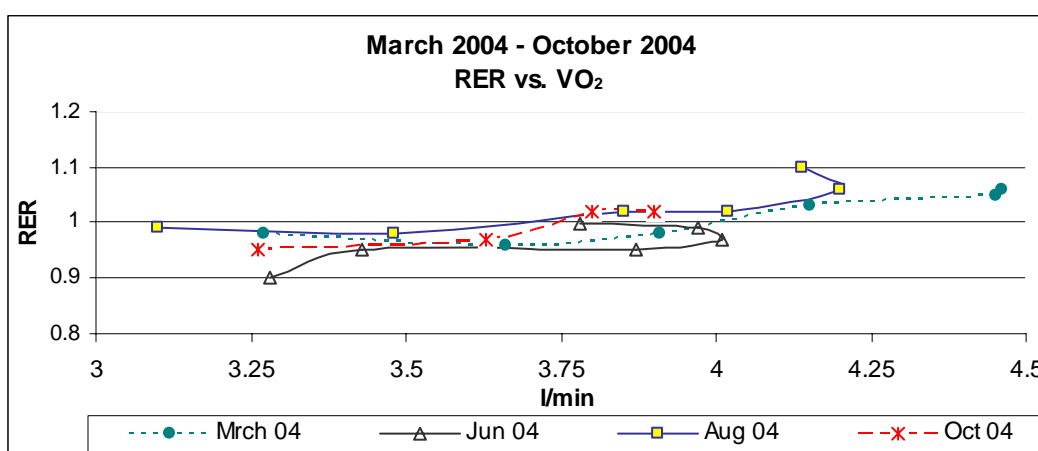


- During March, the best linear relationship was established.
- A linear graph in June was only visible to the value of 4 l/min. After that his VO_2 decreased, while HR continued to increase.
- A decrease in heart rate efficiency was experienced in July, with higher heart rate for each VO_2 . A maximum heart rate of 211 bpm was achieved. This may have been related to the training camp, although CS3 did not participate fully at the camp.

- CS3 had difficulty completing the test during October. His inability to achieve near maximal heart rate, 89 % of HR_{max} achieved in July, indicated that he could have achieved better results.

Graph 141 presents the relationship between the respiratory exchange rate (RER) and oxygen uptake (VO_2). RER indicates the estimated percentage contribution of carbohydrate or fat to energy metabolism during exercise. It is the ratio of carbon dioxide output (VCO_2) to the volume of oxygen consumed (VO_2) (Powers & Howley, 2001).

Graph 141. Respiratory exchange rate for CS3 (Third Macrocycle)



A RER under 1 indicates a desirable level in CS3's capacity to use oxygen to produce energy from fats and carbohydrates for the cycling action. A lower RER indicates greater fat vs. carbohydrate oxidation. In contrast, a RER above 1 indicates hyperventilation associated with anaerobic metabolism and fatigue.

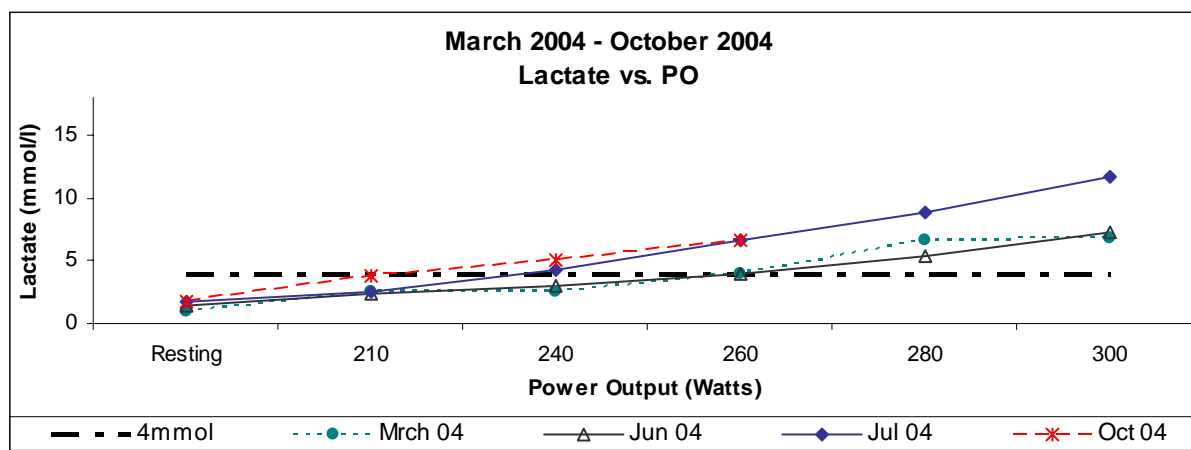
- A maximum RER of 1.06 was reached during the March testing. At 89 % of PPO a RER of 1 was reached with a heart rate of 196 bpm. The plot follows a typical and expected pattern.
- In June, a RER of 1 was reached at the end of the last workload. He was therefore able to cycle the whole test at a RER below 1. Although this could indicate good aerobic metabolism, oxygen consumption itself did not increase in the last 2 workloads. A different interpretation could be an inability to use his anaerobic energy sources. Possibly he had low glycogen stores which could have result in the inability to cycle above a RER of 1. A further possibility could be ability to buffer hydrogen ions, thus not stimulating hyperventilation, on the other hand heart rate

max was also 10 bpm below maximum and possibly this test can not be consider a true maximum effort.

- A maximum RER or 1.1 was achieved in July, indicating a maximal effort in the test. A RER of 1 was reached at 80 % of his PPO.
- The October data was again an indication that maximum results had not been achieved with a RER of 1.02. RER of 1 was achieved at 260 Watts, which is a 4.8 % improvement from July

Graph 142 is an illustration of blood lactate concentrations (mmol/l) at each workload (Watts) during the incremental test.

Graph 142. Blood lactate accumulation for CS3 (Third Macrocycle)



During this study the onset of blood lactate accumulation (OBLA) at 4 mmol/l was used to monitor improvement.

- OBLA was achieved at 83.6 % of PPO (260 Watts) during March and similarly OBLA was achieved at 86.5 % of PPO (263 Watts) in June.
- OBLA was achieved earlier (75.7% of PPO, 234 Watts) in July indicating less endurance.
- OBLA was achieved at even lower power output in October (79 % of PPO, 214 Watts).

Watts achieved at OBLA for the Third Macrocycle indicates that CS3 achieved the highest Watts of 263 Watts in June, and then it decreased by 18.6 % to October.

Wingate Test (sprint power and resistance to fatigue)

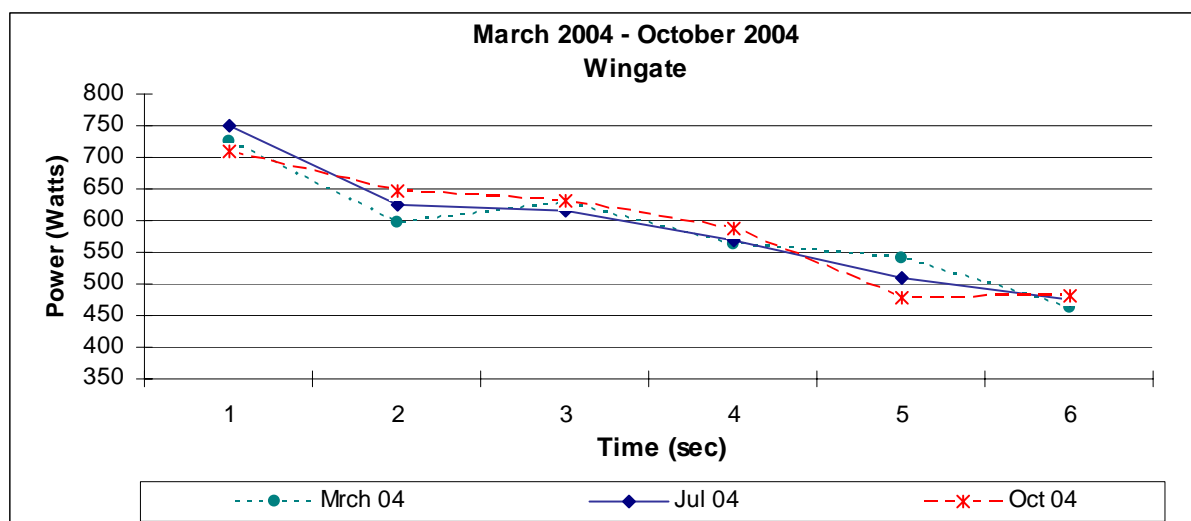
Results of the 30 second Wingate test are presented in Table 68.

Table 68. Values obtained during the 30 second Wingate test for CS3 (Third Macrocycle)

	March 2004	June 2004	July 2004	October 2004
Resistance	9.8 % / BW	9.8 % / BW	9.8 % / BW	9.8 % / BW
Body mass (kg)	64.7	COACH DIDNOT WANT HIM TO DO THE TEST.	65.1	66.7
Peak sprint power (Watts)	724		751	708
Relative peak sprint power (W/kg)	11.2		11.6	10.6
Avg sprint power (Watts)	586		591	590
Relative avg sprint power (W/kg)	9.1		9.1	8.85
Minimum sprint power (Watts)	462		474	480
Avg sprint power / peak sprint power (%)	81%		79 %	83 %
Fatigue index (W/s/kg)	0.14		0.14	0.11

Graph 143 is an indication of the average power output (Watts) during each 5 seconds of the Wingate test.

Graph 143. Sprint power and resistance to fatigue for CS3 (Third Macrocycle)



Peak and mean sprint power is important for tactical attacks during a road race and very important for the track events (1km time trial and 3km pursuit). The peak sprint power (first 5 sec) is important during the start of the track events and the mean sprint power indicates the capacity to sustain maximal sprint power. Track racing is about power output and the capacity to maintain it.

- July indicated a 3.6 % change in peak sprint power and the mean sprint power change with 5 Watts.
- Mean sprint power for October was the same as in July, whereas a 5.5 % decrease in peak sprint power is visible.
- What is most noticeable about the Wingate results is the similarity of the mean sprint power of all the tests indicating consistent ability in this test for CS3. This could also indicate that the Wingate test was not responsive to changes in training for CS3.

1-Hour Distance Trial

The results of this test are presented in Table 69.

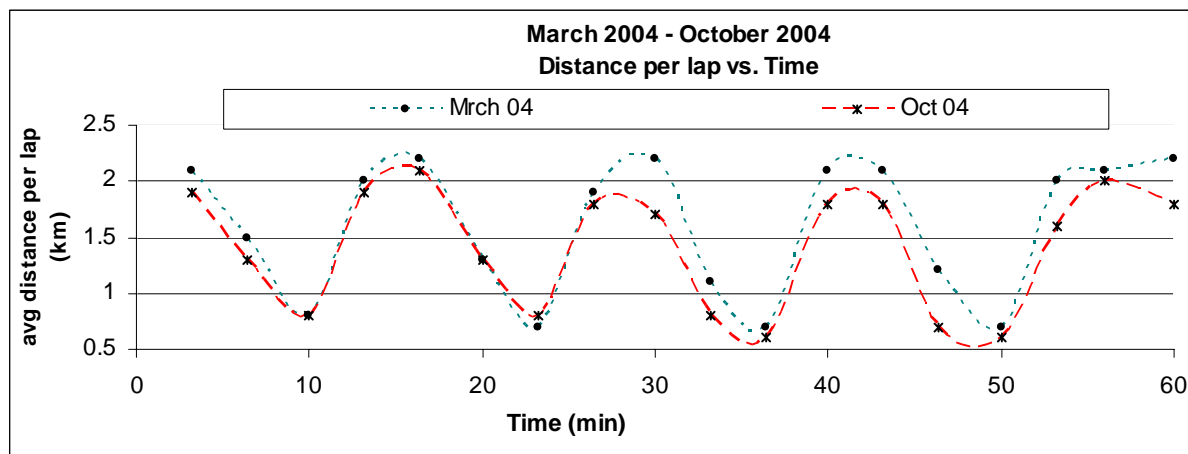
Table 69. Values obtained during 1-hour distance trial for CS3 (Third Macrocycle)

	March 2004	July 2004	October 2004
Total distance (km)	28.9	Couldn't finish the test, stopped after 10 minutes.	25.2
Avg cadence (rpm)	68±13		66±15
Total distance 4% incline (km)	5.1		4.1
Avg cadence 4% incline (rpm)	72±11		57±9
Total distance 8% incline (km)	2.9		2.8
Avg cadence 8 % incline (rpm)	55±1		48±5
Avg heart rate (bpm)	183±8		160±18
Highest heart rate (bpm)	194		182

Total Distance. Graph 144 illustrates the average split distances for each lap over time. For interpretation of the graphs remember from the method section that each lap represent 3 minutes and 20 seconds. The first lap was a flat distance, the second a 4% gradient hill, the third lap a 8% gradient hill, followed by two flat laps, before the first 4 % gradient commenced again and the sequence was repeated four times. The last 10 minutes

was flat. The peak distances were during the flat part of the test and the shorter distances during the climbs.

Graph 144. Lap distance (km) during 1-hour distance trial for CS3 (Third Macrocycle)

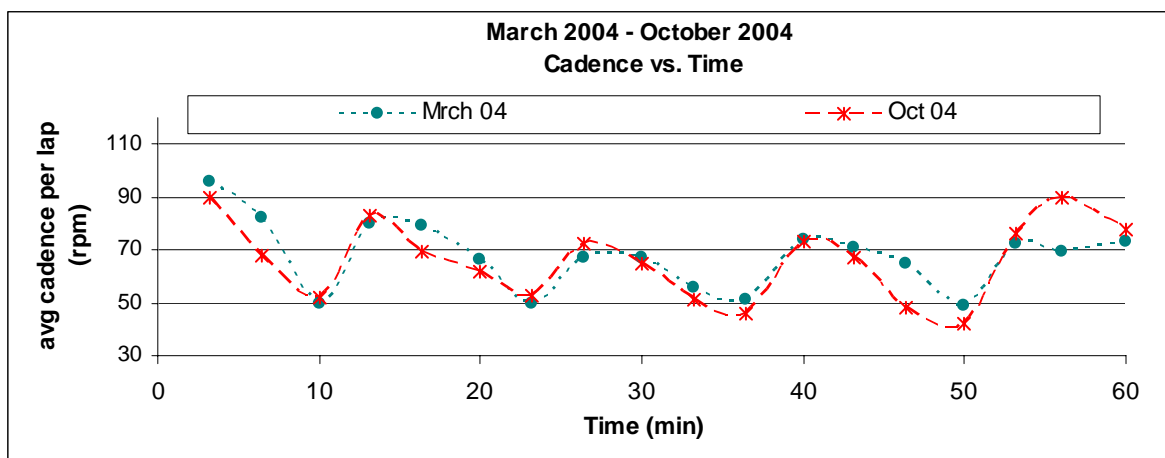


(Rationale for connecting the data points was presented in Chapter Three.)

- The distance covered in March was clearly higher (detail in table). March data shows a good final effort over the last 10 minutes.
- CS3 started the test during July, but couldn't finish the test. When asked why he gave up, he said he just can't do it. He did not want to retry the test on another day.
- The October distance indicated a 13 % decrease in distance since March 2004. A 1 km difference is seen on the total distance covered on the 4 % gradient hill, but no difference is seen on the 8 % hill. It therefore indicates a decrease in distance covered over the flat parts of the distance trial.

Cadence (rpm). Graph 145 is an illustration of the cadence (rpm) averaged over the period of time. The cadence was higher on the flat part of the race and lower on the hills.

Graph 145. Cadence (rpm) selection during the 1-hour distance trial for CS3 (Third Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

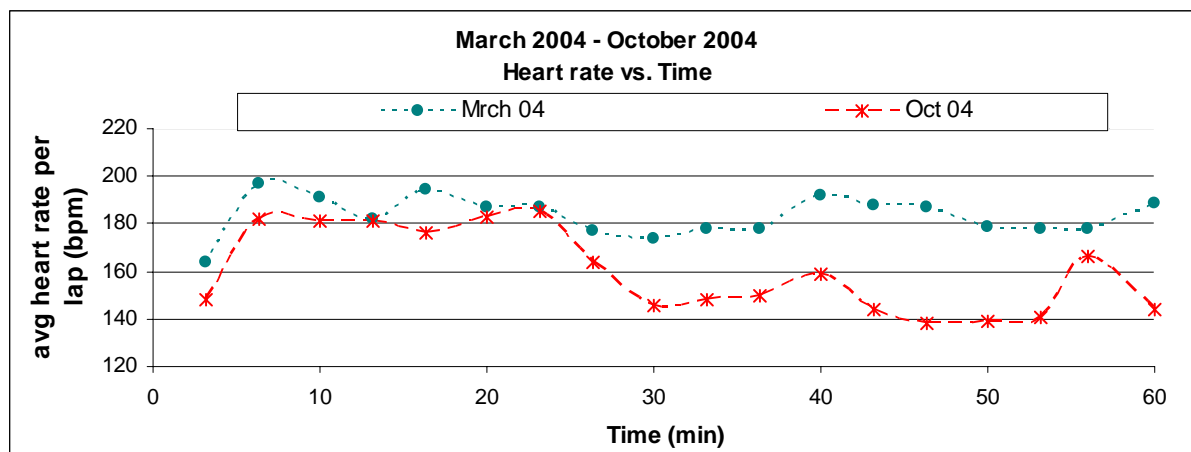
The graph above indicates that CS3 had a similar cadence selection over the three test periods.

- During March, the average cadence during the 1-hour distance trial was 68 rpm and on the 4 % gradient hill, 72 rpm. The cadence selection of the 8 % gradient hill was 55 rpm.
- The average cadence for October was 66 rpm, with an average cadence of only 57 and 48 rpm on the 4 % and 8 % hills, respectively.

A low cadence selection is visible during both tests, with an increase in cadence during the last 10 minutes for the March test.

Heart Rate (bpm). Graph 146 illustrates the heart rate (beats/minute) averaged per lap over the time period of the test.

Graph 146. Heart rate (bpm) during 1-hour distance trial for CS3 (Third Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

The incremental exercise tests indicated that CS3's maximum heart rate was 211 bpm.

- In March, CS3 averaged at 87% of HR_{max} and 96 % of HR_{OBLA} achieved in March.
- In October CS3 average only 76 % of HR_{max} , but managed 95 % of HR_{OBLA} achieved in October.

The October plot indicate an effort to start at the same intensity as in March, but after 23:20 minutes, the effort according to heart rate intensity decreased. Due to a lower HR_{OBLA} in October, CS3 cycled in both tests at 96 and 95 % of HR_{OBLA} , but when taken HR_{max} into consideration, the heart rate intensity during the October test was 11 % lower.

Summary of 1-Hour Distance Trial. CS3 showed a decrease in distance covered during the 1-hour distance trials in Macrocycle Three. The decrease in average cadence of 16 rpm and the decreased percentage of HR_{max} in October is indicative that motivation could have influenced his results.

1 km Time Trial

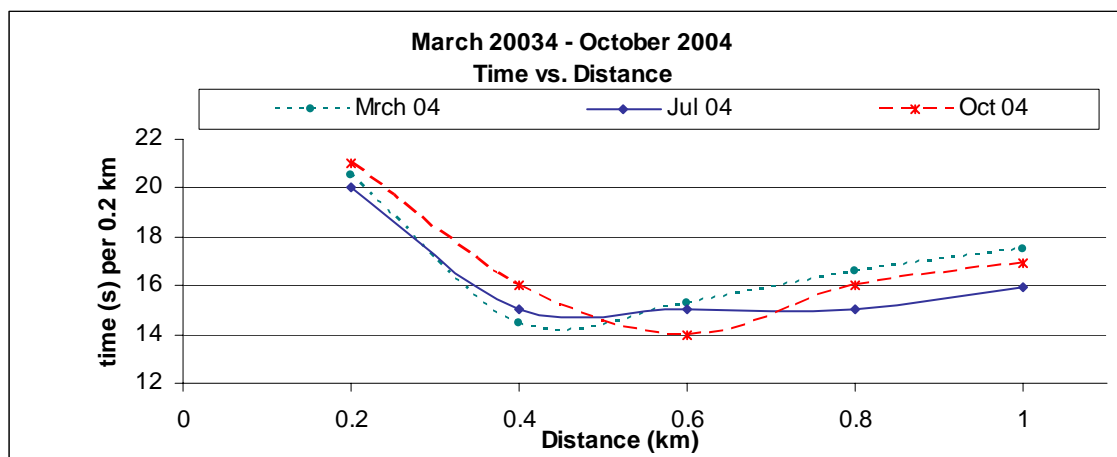
Results of the 1 km time trial are presented in Table 70.

Table 70. Results during the 1 km time trial for CS3 (Third Macrocycle)

	March 2004	July 2004	October 2004
Gear selection	90	90	90
Time (min:s)	1:24.4	1:20.9	1:23.9
Avg cadence (rpm)	111±7	114±10	111±3
Avg speed (km/h)	42.7±4	44.9±6	42.9±6
Avg heart rate (bpm)	182±25	175±28	180±28
Highest heart rate (bpm)	196	197	201

Time / Distance. Graph 147 illustrates the time taken (s) for each 0.2 km over the distance (km) achieved during the 1 km time trial.

Graph 147. Time taken (s) for each 0.2 km during the 1 km time trial for CS3 (Third Macrocycle)



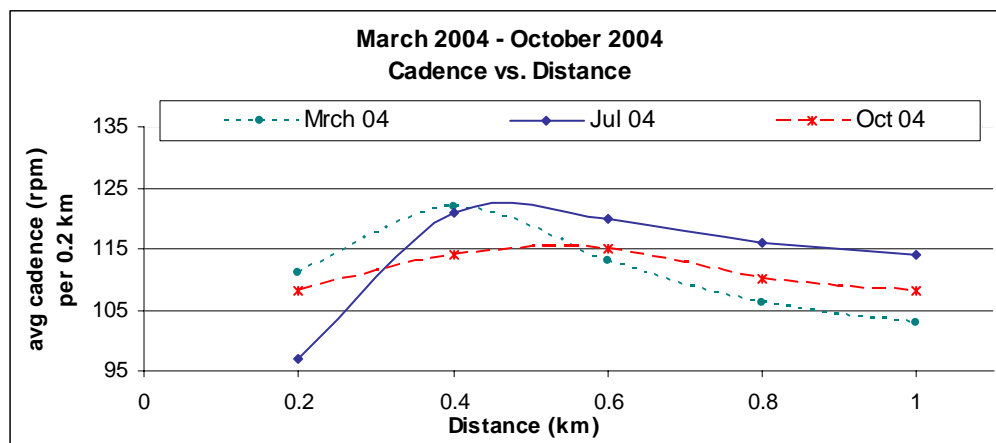
(Rationale for connecting the data points was presented in Chapter Three.)

This graph is an indication of the 1 km track time trial capacity of CS3 and the tactics he used.

- July had the fastest start over the first 0.2 km, with the best average speed of 44.9 km/h.
- October indicated the slowest start, with the best maximum speed between 0.4 km and 0.6 km. The average speed for October was 42.9 km/h, because of slowing down towards the end.

Cadence (rpm). Graph 148 illustrates the cadence (rpm) averaged for each 0.2 km during the 1 km time trial.

Graph 148. Cadence (rpm) selection during 1 km time trial for CS3 (Third Macrocycle)



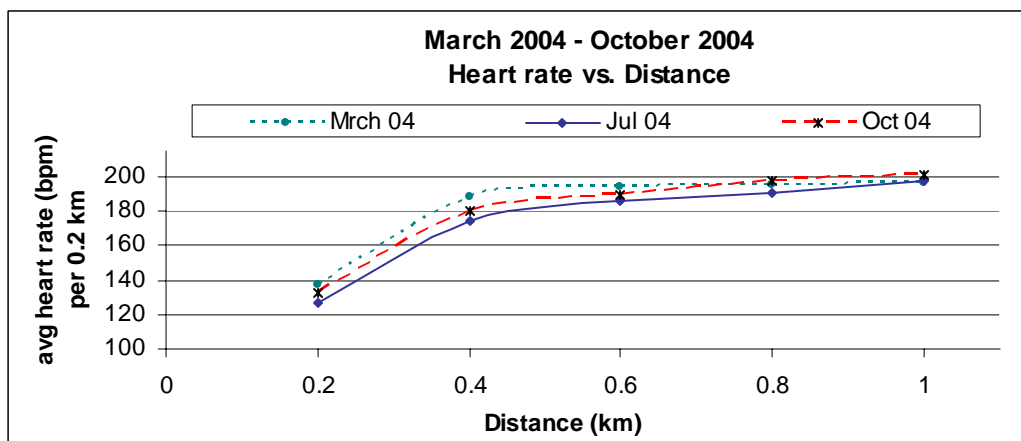
(Rationale for connecting the data points was presented in Chapter Three.)

During all three trials the gear selection was 90. The cadence graphs will therefore also indicate indirectly the speed.

- During March, an average cadence of 111 rpm was maintained. A relatively fast cadence between 0.2 km and 0.4 km was achieved, with a steep drop in cadence to below 105 rpm at the end.
- July indicated a slow cadence at 0.2 km. with an increase in cadence to 0.5 km, where after it slowly decreased towards the end. An average cadence of 114 rpm was achieved.
- During October, an average cadence of 111 rpm was maintained. The peak cadence was achieved between 0.4 km and 0.6 km. A constant cadence was maintained after that indicating a quite different pacing strategy.

Heart Rate (bpm). Graph 149 illustrates the heart rate (bpm) averaged for each 0.2 km over the distance (km) covered.

Graph 149. Heart rate (bpm) during 1 km time trial for CS3 (Third Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

Although heart rate during such a short and intense event is not really indicative of the intensity (Powers & Howley, 2001), it is interesting to see the different graphs.

- During March, an average heart rate of 182 bpm and a highest heart rate of 196 bpm were achieved.
- During July, an average heart rate was lower (175 bpm) but similar maximum heart rate of 197 bpm was achieved.
- October had an average heart rate of 180 bpm and a maximum of 201 bpm.

Summary of 1 km Time Trial. The main goal in the 1 km time trial, is to maintain the speed and therefore muscle or speed endurance is required (Friel, 2003). July had the fastest time, the fastest cadence and the lowest average heart rate.

3 km Time Trial

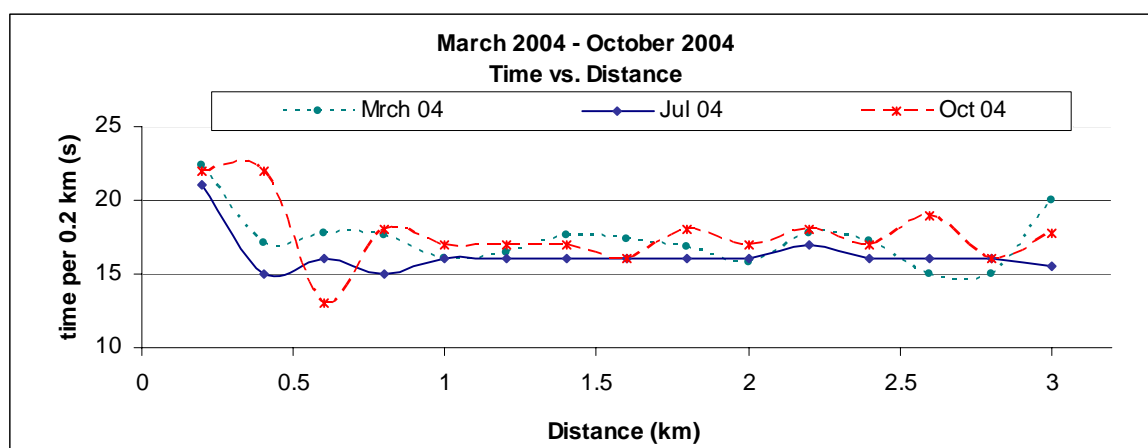
Results of the 3 km time trial are presented in Table 71.

Table 71. Results during the 3 km time trial for CS3 (Third Macrocycle)

	March 2004	July 2004	October 2004
Gear selection	90	90	90
Time (min:s)	4:19.9	4:03.5	4:24.8
Avg cadence (rpm)	104±3	109±2	100±2
Avg speed (km/h)	41.7±3	44.4±3	40.8±3
Avg heart rate (bpm)	188±18	192 ±18	188±20
Highest heart rate (bpm)	204	205	204

Time / Distance. Graph 150 illustrates the time taken (s) for each 0.2 km during the 3 km time trial.

Graph 150. Time taken (s) for each 0.2 km during the 3 km time trial for CS3 (Third Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

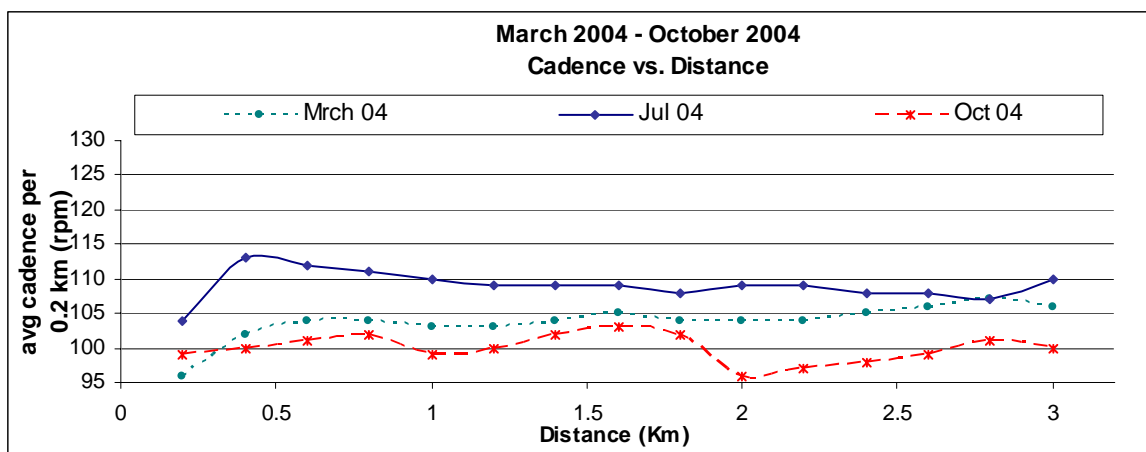
This graph is an indication of the riding capacity during the 3 km track pursuit as well as the tactics used during the test.

- The average speed during March was 41.7 km/h. Over the first 0.2 km CS3 took 22.4 s, from here he accelerated to cycle at an average of ± 17 s per 0.2 km. His last 0.2 km decreased to 20 s, indicating fatigue.

- July data indicated a faster start (21 s for the first 0.2 km), and an average of 16 s per 0.2 km. Over the last 0.2 km he accelerated slightly to 15.5 s. A better average speed of 44.4 km/h was achieved.
- October data indicated again a slow start over first 0.4 km with an average of 22 s per 0.2 km, then he accelerated to a fastest 0.2 km of 13 s. Speed was then maintained at a relatively slow 17 s per 0.2 km, for an average speed of 40.8 km/h over the 3 km.

Cadence (rpm). Graph 151 illustrates the cadence (rpm) averaged during the 3 km time trial.

Graph 151. Cadence (rpm) selection during 3 km time trial for CS3 (Third Macrocycle)



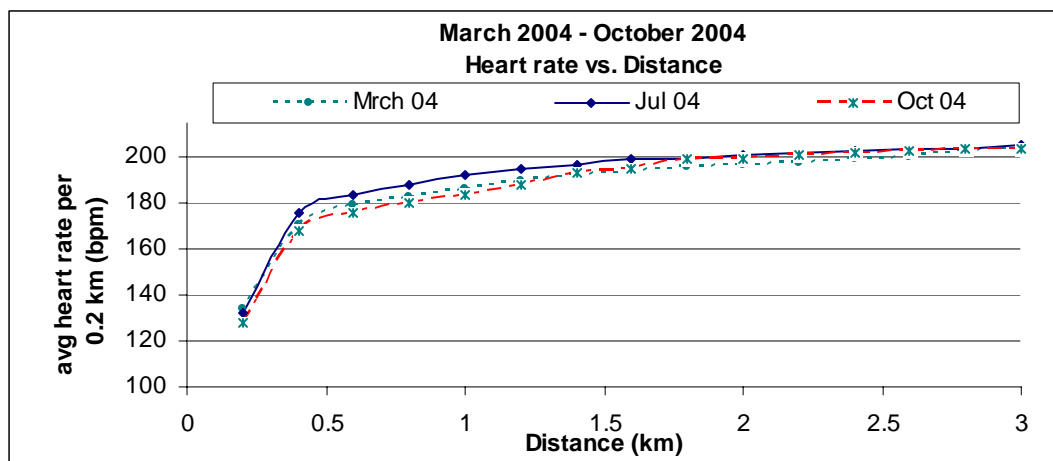
(Rationale for connecting the data points was presented in Chapter Three.)

A gear of 90 was used in all three trials.

- March data indicated a very constant average cadence after the first 0.4 km and an average cadence of 104 rpm was achieved.
- July data indicated the fastest cadence throughout the test, with an average cadence of 109 rpm.
- October data indicated a cadence that varied a lot throughout the test, but an average of 100 rpm was achieved.

Heart Rate (bpm). Graph 152 illustrates the heart rate (bpm) averaged per 0.2 km over the distance (km) covered.

Graph 152. Heart rate (bpm) during 3 km time trial for CS3 (Third Macrocycle)



(Rationale for connecting the data points was presented in Chapter Three.)

Although heart rate during such short and intense events is not really indicative of the intensity (Powers & Howley, 2001), it is interesting to visualize the different graphs.

- The average heart rate for the three tests varied little (between 188 bpm to 192 bpm). The highest heart rate varied little (between 204-205 bpm).

Summary of 3 km Time Trial. The interesting fact for the 3 km time trial is that the fastest time was achieved in July. July data indicated the fastest average cadence and tactics of starting fast and maintaining the speed as fast as possible towards the end.

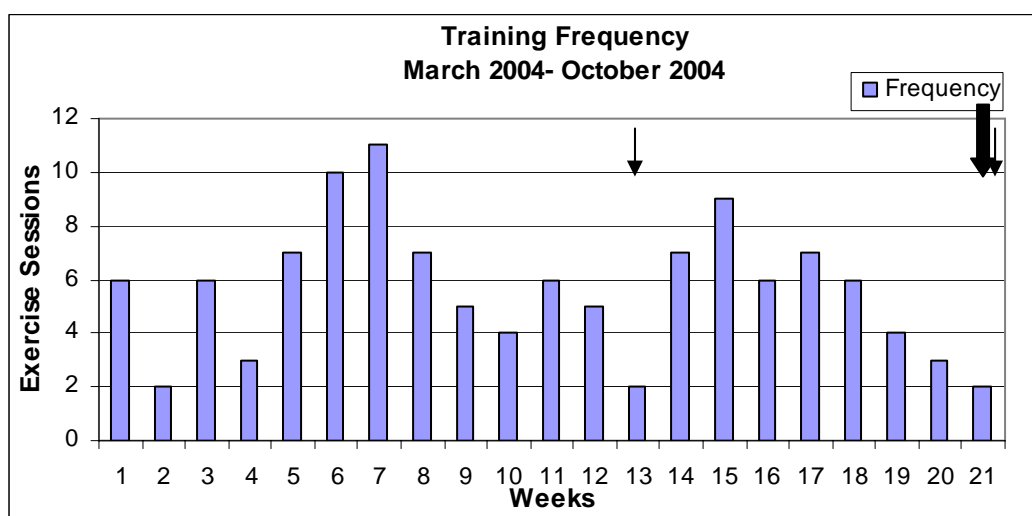
Training

During the Third Macrocycle, the heart rate data of CS3 was used to determine his training intensity, volume, frequency and the mode of training.

Training Frequency

Graph 153 illustrates the exercise sessions per week for the First Macrocycle.

Graph 153. Training frequency for CS3 (Third Macrocycle)



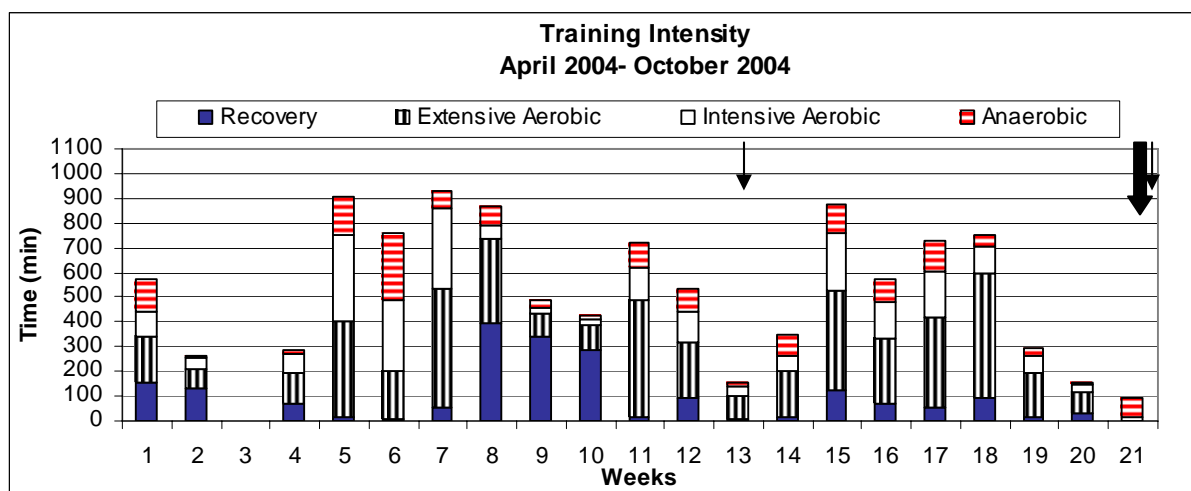
↓ Indicative of the competition times. ↓ Indicative of testing times.

During weeks 1-6 infrequent training is seen. This was during CS3's exam time and training was not the number one priority. Weeks 5 – 8 represent holidays and more training sessions were possible due to no other obligations. CS3 was able to train on average of 5.4 sessions per week during the first 12 weeks of Macrocycle Three. Week 13 indicates low training frequency. On average, 6.2 training sessions per week were conducted during weeks 13-18. His training frequency is therefore on average not too infrequent. Not all training was recorded during weeks 20-21.

Training Intensity

Graph 154 is an illustration of the average heart rate training intensities during each week.

Graph 154. Training intensity for CS 3 (Third Macrocycle)



↓ Indicative of the competition times. ↓ Indicative of testing times.

Table 72. Percentage of training time in each training zone for CS3 (Third Macrocycle)

Weeks	Recovery Zone (<70%)	Extensive Endurance (70-80%)	Intensive Endurance (80-85%)	Anaerobic (>85%)
1- 6	13.7% (382min)	34.9 % (974 min)	30.3 % (846min)	21.1 % (588 min)
7-12	29.9 % (1187 min)	42.9 % (1702 min)	17.4 % (691 min)	9.8 % (385min)
13-18	10.5 % (359 min)	52.8 % (1814 min)	22.6 % (777 min)	14.1 % (483 min)
*19-21	8.7 % (47 min)	49.1 % (265 min)	19.8 % (107 min)	22.4 % (121min)

* Not all training data was gathered in Weeks 19 -21.

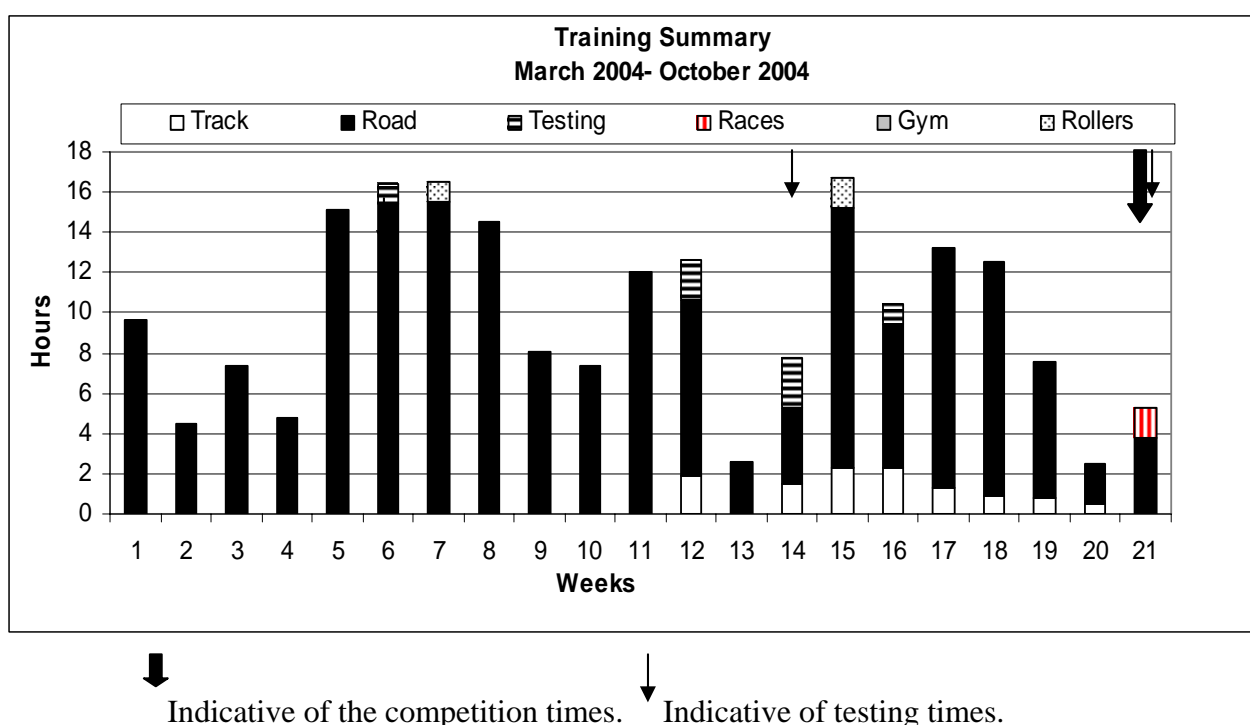
Data in this graph is only heart rate data gathered (Polar S720). During the first six weeks of Macrocycle Three, the focus of the training was to improve base training and to do most of the training between 70-80% of HR_{max} . Forty eight percent of his training was conducted at lower than 80 % of HR_{max} , with 21.1 % of his training higher than 85 % of HR_{max} . This indicated that a great percentage of his training was conducted at a too high percentage. During weeks 7- 12 his training volume needed to increase and the aim was to do a greater amount of training between 80-85 % of HR_{max} . Instead his training time below 70 % of HR_{max} increased. Recovery rides have no training effect except to help the body to

recover for a next training session. 42.9 % of his training was spent between 70-80 % of HR_{max} . This was a 12 % increase from the previous 6 weeks. Training above 80 % of HR_{max} equalled 27.2 %. During weeks 13-18 the training aim was to increase the training intensity and training volume should reach its maximum. CS3 training data indicated a 9 % decrease in training volume. His training intensity indicated that 61.3 % of training time was spent below 80 % of HR_{max} . Training time above 80 % of HR_{max} did increase, but was only 39 % of training time. During this time training should become more specific for competition and high intensity training is important. Not all training data was collected during weeks 19 -21. High intensity training with a great amount of rest like track training, may result in a greater amount of training recorded as recovery and little time at maximum due to the type of training.

Training Volume and Training Modes

CS3 noted the different training modes he used, electronically (Polar Precision Performance Software). Training volume (km) was impossible to determine given that he used so many different modes of training, many of which could not be quantified in km. Hence the volume of training is expressed as duration (hours/week). Graph 155 illustrates the different training modalities used during the Second Macrocycle.

Graph 155. Training summary for CS3 (Second Macrocycle)



The training summary is an indication of the different training modes that CS3 used. CS3's main training modes were road training, track training and roller training. Road training made up 96 % of the training time of CS3 during the first 12 weeks of Macrocycle Three. This decreased to 79 % and 59 % of his training during Weeks 13- 18 and 19 – 21. This indicates the increase in track training from no training on the track during Weeks 1 -6 and 7-12, to 13 % and 4.7 % of training on the track during Weeks 13- 18 and Weeks 19 -21, respectively. This indicates that CS3 tried to be specific in his training for competition, but his time on the track was too limited to really adapt him to perform on the track. His lack of competition or races before the Paralympic Games indicates a lack of competition training.

General Summary of Training

During the Third Macrocycle the main focus was to excel in competition at the Paralympic Games. CS3's training indicated a high percentage of training on the road during all phases. His time spent on the track should increase if he wants to excel in track races. He spent a great amount of time in the heart rate zones lower than 80 % of HR_{max} , during weeks 13- 18, which is the time he should have increased training intensity. This lack of training at higher heart rate intensity could have resulted in not being able to compete at his maximum.

Direct Factors Targeted during the Third Macrocycle

The research question guiding this study focused on the management of selected direct factors important for sport performance management. The following rating scale reflects the investigator's perceptions of the degree of success in managing these factors.

Direct Factor	Score	Reasons
Performance Assessment	3	The main goal for CS3 was to be competitive at the Paralympic Games. Performance evaluation at competition is difficult to make due to various circumstances that influence the outcomes. Some difficulties were experienced during testing. The influence and respect towards the coach's attitude towards testing made it difficult to convince CS3 of the training. The closer the competition got, the training was seen as taking training time away and not adding to his training. This could have played a major role in motivation during the tests. His October test results are not as expected and various results indicates either a lack of motivation or great problems with his training due to the low results he got.
Periodised Planning of Training	2	A great emphasis was placed on road training and lower intensity training. No changes were made towards the end of the Macrocycle to increase intensity and specificity of training. CS3 can therefore improve in his training intensity as well as specificity. His training volume reached the aim of 15hrs a week a few times, during maximum volume weeks.
Feedback on Training	3	No feedback of training during the last two weeks during competition. The specificity of feedback should improve.
Training Sessions	3	Training sessions weren't synchronized between the track and road coach. A lot of training was done as part of a training group, and the specific goals for a day were not always set.
Training Camp	1	CS3 was not fully committed to the training camp, and many times chose to cycle with his own training group. He also couldn't attend the full camp, due to study commitments.
Sports Medicine Services & Products	5	Full service available. Full medical, nutritional, psychological and vision assessment completed at first training camp in May, 2005 by the team professionals. Feedback was given to CS3 by them. Due to confidentiality, no feedback was given to the investigator. During this time CS3 went on his own account to a physiotherapist. CS3 received a new road bicycle as well as competition wheels.

Score = Point out of 5, with 0 not achieved, 5 fully achieved.

General Summary of Direct Factors Targeted for CS3

The research question guiding this study focused on the management of selected direct factors important for sport performance management. The following is a summary of the selected direct factors, the outcomes as well as the factors that could have influenced the outcomes.

Performance Assessment

Competitions

CS3 was able to compete in all the major competitions available to him.

Physiological Monitoring

Anthropometry. The data indicated that CS3 had an average fat percentage of 9.9% after the Paralympic competition, with the range 7.2 – 9.9% over the three macrocycles. Of all the testing his fat percentage was the highest after the Paralympic Games. This could have been due to the fact that testing was conducted after the Games, and that free food in the Paralympic Villiage could have result in a higher fat percentage. According to Winnick & Short (1995), his cerebral palsy should not have influenced his skinfold measurements. CS3's average body mass at competition time was 64.2 kg with a range of 61.6-66.7 kg. From the first testing in April 2003, to the last testing in October 2004, his weight increased by 10 %. His average BMI (bodymass index) at competition time in October was 22.9 kg/m². Comparing this to the anthropometric characteristics of an able-bodied cyclist, his average fat percentage was within the range of 8 -10 %, and his BMI is equal to that of a time trial specialist (Lucia et al., 2001), but higher than that expected from a climber (19-20 kg/m²).

Incremental Exercise Test to Exhaustion: Pedaling Efficiency. Oxygen uptake at a given sub maximal workload for children with cerebral palsy has been found to be equal to their able-bodied peers (Rose et al., 1993), but other studies found oxygen cost is higher for persons with cerebral palsy (Bowen et al., 1999; Unnithan et al., 1996).

At the first test during March, 2003, CS3 had a maximum PPO of 287 Watts and a VO₂max of 3.96 l/min. The peak values achieved in PPO and VO₂max were during the April, 2004 testing, with values of 311 Watts and 4.46 l/min respectively. This could be

explained by the fact that he had just been selected for the Paralympic Games.

Alternatively associated with the National Championships may have allowed him to perform at his best in the laboratory as well. His maximum values decreased from April 2004 to October 2004 (June and July included), that is indicative that his training was not conducted in the correct way to improve peak values. Literature indicates PPO as an important determinant of performance (Coyle et al., 1991).

In a summary by Mujika & Padilla (2002), cyclists are classified according to training and racing status. CS3 falls into the well-trained category that showed values for PPO/kg between 5.0 - 6.0 W/kg and VO_2 max values between 5.0 - 5.3 l/min. CS3's maximum value for VO_2 max was 15.8 % lower (5.3 l/min) and the PPO/kg value 20 % lower (6 W/kg) estimated for well-trained cyclists.

The investigator calculated correlation coefficients using Pearson Product Moment Correlation, but no statistically significant ($p < 0.05$) correlations were found between the different laboratory tests and the total as well as percentage of training time spent in each zone.

The incremental tests to exhaustion from October, 2003 – October, 2004 (6 tests), were conducted on the LODE ergometer, able to determine the power output of the left and right leg separately as well as the range of power output across each revolution of the pedal. Table 73 is a summary of the average data of the six different test sessions.

Table 73. Summary of the pedal force measurements during incremental tests to exhaustion

	210 W	240W	260W	280W	300W	320W
Avg RPM	91±3	94±5	96±6	96±3	90±7	87±4
Avg Watts Left	132±6	149±2	160±3	170±2	181±0.9	192±5
Avg Watts Right	92±3	104±4	115±3	123±3	133±4	142±2
Avg Max Watts Left	489±27	517±65	576±39	599±19	623±19	650±2
Avg Max Watts Right	350±52	419±18	442±8	454±9	480±10	510±6
Avg Min Watts Left	-50±13	-50±19	-46±18	-40±12	-29±5	-31±1.4
Avg Min Watts Right	-97±17	-92±21	-84±19	-71±11	-51±9	-40±5
Efficiency	88±3	89±3	91±3	93±1	96±1	97±0.7
Ratio L	59±1	59±1	58±1	58±0.6	57±0.5	57.5±0.7
Ratio R	41±1	41±1	42±1	42±0.8	43±0.5	42.5±0.7

- **Average RPM.**

The average rpm reported is the average revolutions per minute at each workload over the six test sessions. During the first two workloads, which are the easy workloads (210 and 240 Watts), the average rpm's sustained by CS3 were ± 91 and 94 rpm. The average rpm increased slightly during the next two workloads (260 & 280 Watts) increased to ± 96 rpm, with a decrease to ± 90 rpm at 300 Watts, and ± 87 rpm at 320 Watts.

- **Efficiency.**

An efficiency of 100 is seen as a perfect cycling action with no resistance applied against the cycling action. Resistance is applied during the upstroke by the weight of the lower limb which has to move or be moved against gravity. Resistance can be relieved in two ways: 1) actively, by "pulling" the pedal up (hamstring action of the same limb), or 2) passively, by the force of the downward stroke of the opposite leg. A negative value for the average minimum Watts per leg indicates that forces were applied against the pedaling action. It is interesting to note that the easier the workload, the more negative force was applied by CS3 to the pedals. The high cycling cadence with little resistance may result in a lack of muscle coordination, especially when taking cerebral palsy into consideration (Parker et al., 1992). The efficiency improved from a mere 88 % efficiency at 210 Watts, to an efficiency of 97 % at 320 Watts. This indicates that CS3's cycling action is very efficient and essentially not very much affected by his cerebral palsy.

- **Left - Right Leg Ratio.**

This ratio is an indication of the percentage of the total Watts each leg produced during each workload. During the easy workloads, the ratio between the two legs was 59: 41, left to right leg. This improved slightly as the workload increase and the best ratio achieved was during the last workload of 300 Watts, where a ratio of 57: 43, left to right, was achieved. The difference in the work conducted by the left and right leg stayed quite similar, which indicates that when the one leg produced more power, the

other did the same. Percentage of the maximum power each leg produced was the same throughout, with the maximum power of the right being consistently less.

Incremental Exercise Test to Exhaustion: Heart Rate Efficiency. Maximal heart rate used during the macrocycles was 211 bpm. The maximal heart rate achieved in the incremental exercise test to exhaustion varied between 189-211 bpm. During October 2004, the maximum heart rate of 189 bpm was low and indicates that CS3 didn't complete the test to maximum. Of importance is that at submaximal levels, the goal was to cycle at lower heart rate intensities during the test. After each Macrocycle, the test at peak competition indicates better heart rate efficiency. This indicates that CS3 was able to ride at his lowest heart rate during the three Macrocycles at the Paralympic Games. Although the October test didn't last long, the first four workloads indicate greater heart rate efficiency.

Incremental Exercise Test to Exhaustion: Respiratory Exchange Rate. The longer a cyclist can ride under a RER of 1, the better his/her capacity to use oxygen to burn fat to produce energy for the cycling action. This resulted in saving the glycogen stores for higher intensity work later in the race, when needed. During the First Macrocycle, CS3's ability to cycle at lower RER values according to VO_2 intensity. This improved further during Macrocycle Two with a RER of 1 being reached at a VO_2 of 4 l/min. During the June testing in Macrocycle Three, CS3 did his entire test at a RER below 1. This could be indicative that his training lacked high intensity training or that his carbohydrate stores were depleted. His ability to utilize his aerobic metabolism, decreased towards July and October 2004, which was not the aim.

Incremental Exercise Test to Exhaustion: Lactate Accumulation. During June 2003 (First Macrocycle) he achieved a better OBLA_4 than April or October 2003, and also spent substantially more time training in the extensive aerobic training zone and the intensive aerobic zone (see graph 120). In the Third Macrocycle CS3's best capacity to prevent lactate accumulation was during March and June 2004. Watts at OBLA were in March 2004 at 84 % of PPO and in June 2004 at 87 % of PPO. Training could not explain the values for March. But the training before the June 2004 testing was similar to the previous year, high in volume and with substantial time spent in the extensive and intensive aerobic zones (see graph 154). During all three Macrocycles, HR_{OBLA} varied

between 169-193 bpm. In June 2004 CS3 had a HR_{OBLA} of 91 % of HR_{max} . Mujika & Padilla (2001) indicate that for time trials shorter than 30 minutes, HR_{OBLA} is a good indicator of HR to be achieved during time trials.

CS3's capacity to cycle at high lactate values decreased from July 2003, to October 2004. In July 2003 CS3 was able to push his maximal lactate value to 16.7 mmol/l, in October 2004 his maximal values was 6.7 mmol/l, indicating his lack of commitment.

No statistically significant correlations ($p < 0.05$) were found between percentage training time spent in the intensive training zone and $Watts_{OBLA}$.

Wingate Test. The Wingate 30 second anaerobic test was previously found to be a valid test to evaluate peak sprint power and anaerobic capacity for persons with cerebral palsy (Parker et al., 1992; Tirosh et al., 1990). Cyclists with cerebral palsy find it difficult to produce power at high speed (Parker et al., 1992). Peak sprint power in this study was determined from the best 5 second period. The mean sprint power was the average sprint power produced over 30 seconds. Highest mean (604 Watts) and peak (752 Watts) sprint power for CS3 was found in January, 2004. This is indicative that although no track training was done, the peak values increased after base training. This was an unexpected result, but it could be explained by the acute reduction of training volume in Week 12, just prior to testing (see graph 137). When comparing the peak and mean sprint value of March, 2003 with October 2004, less than 1 % change was found in the Watts/kg for both. When comparing the Watts an 8 % increase was seen in the peak values from March, 2003 to October, 2004, and a 10 % increase in mean sprint power is found. The fact that peak sprint power and mean sprint power is mainly indicative of track performance where Watts is more important than Watts/kg, his improvement is therefore good.

No statistically significant ($p < 0.05$) correlation between training and peak or mean sprint power has been found for CS3. Track time trials did not correlated statistically significant with any of the values of peak or mean sprint power for CS3.

1-Hour Distance Trial. The 1-hour distance trial performances fluctuated a great deal. The distance covered by CS3 in the 1-hour distance trial improved from 27.4 km to 34.5 km (best performances October, 2003). From October 2003 it decreased to a lowest value in October 2004 of 25.3 km. Motivation plays a huge part in time trial performance and a lack of motivation in October was definitely a factor. CS3's average cadence on the

1-hour distance trial varied between 68 rpm and 80 rpm. CS3 never showed a capacity to cycle at a higher cadence and his average cadences on the 4 % and 8 % hills were low. Swain and Wilcox (1992) found 84 rpm on hills to be the most economical. CS3 can therefore work on improving his cadence cycling uphill as well as on the flats.

The average heart rate achieved during all of the 1-hour distance trials was above 85 % of HR_{max} , except in October 2004. A study by Padilla et al. (2000) found that in professional road cycling during a tour, the cyclists are able to cycle at 80 ± 5 % of their HR_{max} during the long time trials and 85 ± 5 % of their HR_{max} during shorter time trials. During uphill time trials the professional cyclists were only able to achieve 78 % of their HR_{max} . CS3 therefore showed he had the capacity to cycle at a high percentage of his HR_{max} during the 1-hour distance trials. Pacing strategy regarding power output in varying external conditions is found to be useful, but the use of heart rate has been questioned (Atkinson & Brunskill, 2000). It is interesting to note that a constant pacing at constant external conditions has been found to be optimal, but at varying external conditions like hills or winds, adapting power output to the conditions result in optimal pacing (Atkinson & Brunskill, 2000).

No statistically significant ($p < 0.05$) has been found between the 1-hour distance trial data for CS3 with either laboratory performance or training data.

1 km Time Trial. The best time trial was during January, 2004 with a time of 1:12.2. It was the only time when he used an 88 gear and an average cadence of 126 rpm was achieved. The average cadence in a 1 km time trial at able body World Championships has found to be 127 rpm (Craig & Norton, 2001). The question is: would the increase cycling cadence be detrimental for the cerebral palsy cyclist due to an increased lack of coordination (Parker et al, 1992)? When CS3 averaged a 126 rpm he achieved his best time. Between the time of the 1 km and 3 km time trial performance a statistically significant correlation has been found ($r=0.97$, $P < 0.05$) using Pearson product moment correlation. This indicates a slower 1 km time will result in a slower 3 km time.

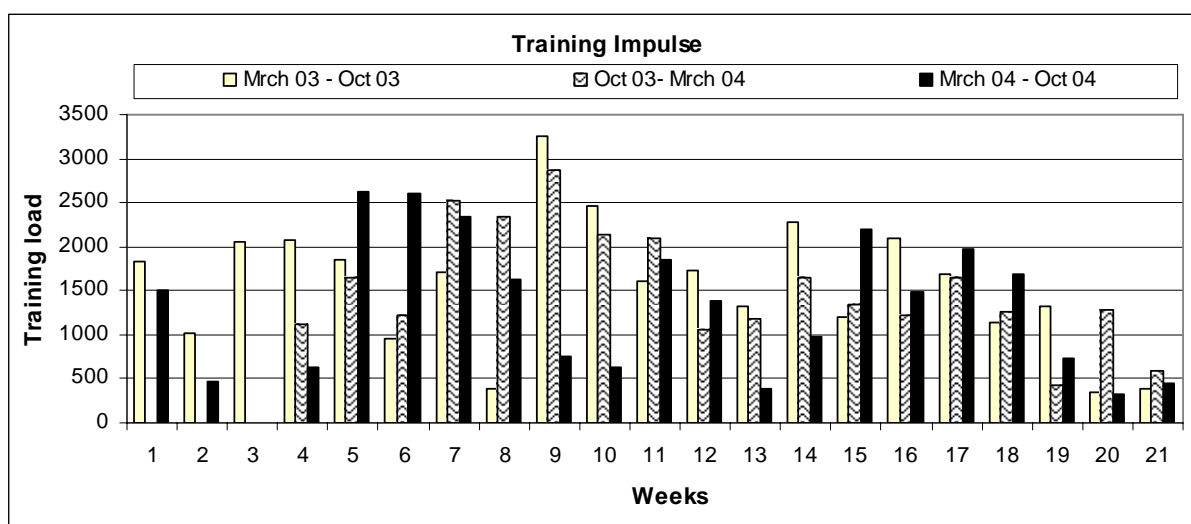
3 km Time Trial. The best 3 km time trial was during January, 2004 with a time of 3:42. CS3 used an 88 gear and an average cadence of 121 rpm was achieved. Average cadence (gear not taken into consideration) correlated statistically significant ($r = -0.98$, $p < 0.05$) with speed achieved in the 3 km time trial.

Periodised Planning of Training

An interesting indicator of training load is “training impulse” (Esteve-Lanao et al, 2005; Foster et al, 2001, Lucia et al, 2003; Mujika et al, 1996). Training impulse is calculated by multiplying the training time in each zone with the fixed factor allocated to that training zone. The total of the training impulse per training zone per week is therefore the total training impulse for the week.

Graph 156 is an illustration of the comparison between the training impulses for the three macrocycles.

Graph 156. Training impulse for all three Macrocycles for CS3



* Training data for weeks 19 – 21 was not always complete.

Graph 156 presents a comparison between the periodisation of the three macrocycles. The training load indicates that the maximum training load achieved by CS3 was in the First Macrocycle during Week 9, with a load of 3254.

Table 74. Break down of training loads per meso-cycle for Macrocycle Two and Three for CS3

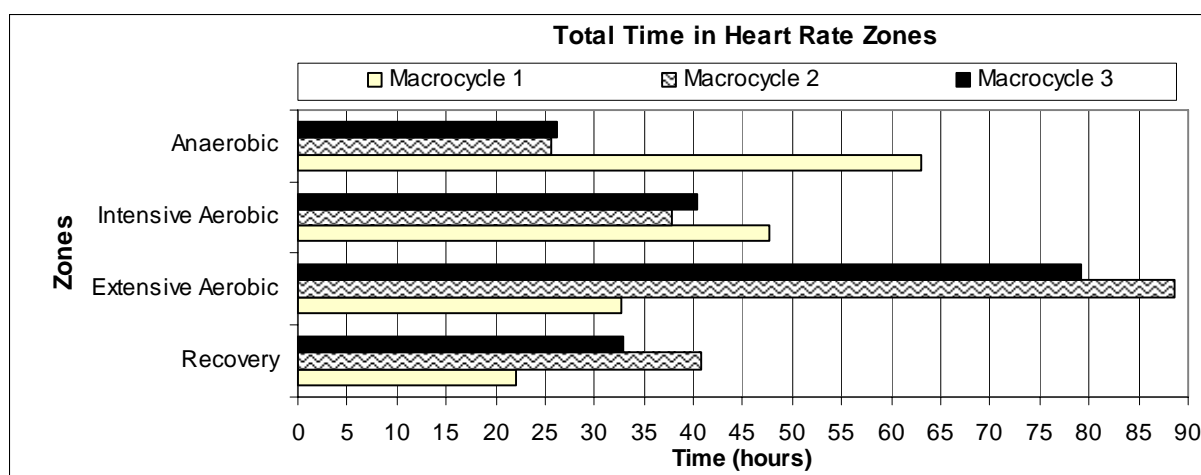
Time	First Macrocycle		Second Macrocycle		Third Macrocycle	
	Load	% Of Total Training	Load	% Of Total Training	Load	% Of Total Training
Weeks 1-6	9791	29.9	3997	14.5	7808	29.4
Weeks 7-12	11156	34.1	13015	47.2	8589	32.2
Weeks 13-18	9752	29.8	8299	30.1	8733	32.8
Weeks 19-21	2050	6.2	2289	8.2	1503	5.6
Total Training	32749		27600		26633	

There was a difference of 18.7 % in total training load between Macrocycle One and Three. The spread of training load through the mesocycles did differ. The initial mesocycle in each macrocycle indicated a 60 % increase in training load from the First to Second Macrocycle, with a 49 % increase towards the Third Macrocycle. Weeks 13- 18 is meant to be the mesocycle with the highest training load due to a maximum training volume and as well as a high intensity of training. But, Weeks 7-12 in all three macrocycles indicated the highest workload of the specific macrocycle. Approximately 30 % of a macrocycle's training load was conducted during Weeks 13-18 of all three macrocycles. The training load data indicates that CS3 is capable of training at higher training loads than he did in the Second Macrocycle and Third Macrocycles. The planning of his training can improve and this should be studied in conjunction with the training intensities.

Time Spent in Each Training Zone

Periodisation of a yearly plan incorporates the different intensities used. Graph 157 is an illustration of the time spent in each heart rate zone during the three Macrocycles.

Graph 157. Training time spent in each heart rate zone for CS3 (1st, 2nd and 3rd Macrocycle).



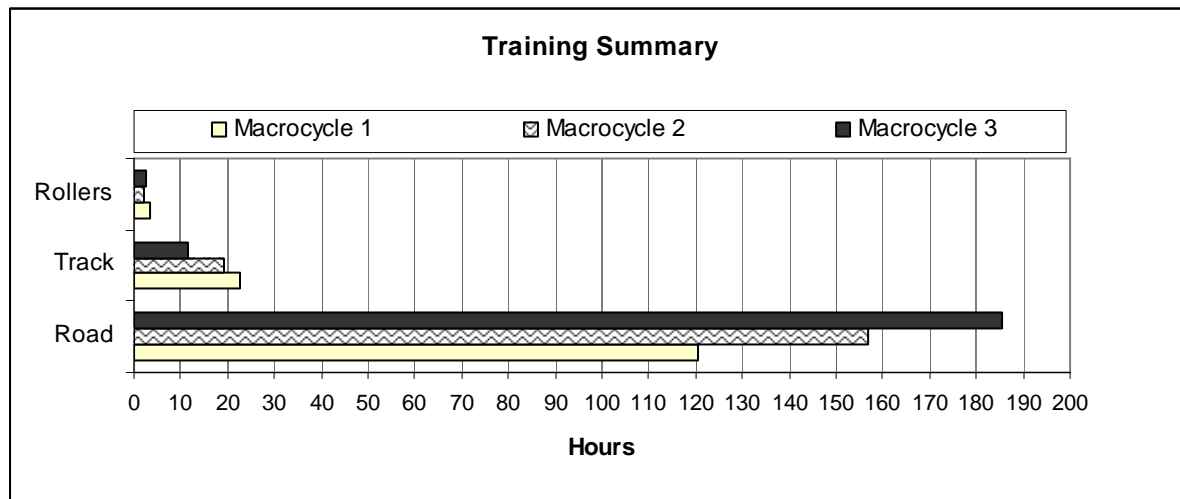
During Macrocycle Two and Three most of the training time was spent in the extensive aerobic zone (70-80% of HR_{max}). This is in sharp contrast with the First Macrocycle where most of the training was done in the anaerobic training zone. After the First Macrocycle, emphasis was on improving the base training of CS3. Time spent in the extensive aerobic zone increased with 170 % from the First to the Second Macrocycle.

Taking into consideration that CS3 had Christmas holidays during the Second Macrocycle where no other commitments had an influence on his training, long hours of training were possible. Of concern is not the time spent in the extensive endurance zone, but the relative percentage of time spent in the intensive aerobic zone. The intensive aerobic zone is necessary to prepare the body for high intensity competition. Less than half of the time spent in the extensive aerobic zone, during the Second Macrocycle was spent in the intensive aerobic zone. The time spent in the intensive aerobic zone for the Third Macrocycle was half the time spent in the extensive aerobic zone.

A Pearson product moment correlation was conducted to determine the relationship between training time spent in the different zones and modes, as well as some performance factors. The only statistic significant correlation was between the average heart rate achieved in the 1 km time trial and training time spent in the anaerobic zone correlates positively ($r=0.98$; $p<0.05$).

Training Summary

Graph 158. Time spent in training modes (road, track and rollers) for CS3



Time spent doing road work increased with 30 % from the First Macrocycle to the Second and a further 18 % in the Third Macrocycle. Track training decreased from the First Macrocycle to the Second with 15 %, and a further 40 % to the Third Macrocycle. It therefore supports the negative correlation, for when road training increased, track training decreased. Roller training formed a small part of CS3 training, and is only used when truly necessary.

Feedback on Training

The training log was found to be a nuisance for CS3. Most of his training feedback was through email and the Polar Precision Software. CS3 did not always monitor his training and heart rate at competition times or the few weeks before competition, due to fear of a psychological effect.

Training Sessions

Track training sessions were conducted as the coach planned. The road training was mostly with a training group or a training partner, especially during the Third Macrocycle. During the Second Macrocycle, weeks 7-12, he trained on his own. Specific focus or goals for training sessions were lacking and should improve. A written explanation of what he wants to achieve in each training session and the plan forward, from the coach would be beneficial.

Training Camps

The training camp in the First Macrocycle served its purpose to warm CS3 to the study but also explained what periodisation of training is. The Paralympic Training Camp, seemed not to serve the purpose when one looks at CS3's commitment to train with the rest of Paralympic Squad. It needs to be remembered that his classes started during the second week of the training camp.

Sports Medicine Services and Products

The only time that financial support was available for CS3 for sports medicine services and products was during the Third Macrocycle. Some of the sports medicine services were required from DISSA (the federation), such as a medical evaluation, nutritional evaluation, visual evaluation as well as a psychological evaluation. This was conducted at the start of the Third Macrocycle. CS3 attended a physiotherapist at his own cost during this time period.

Conclusion

To conclude, great improvement in training time is seen, but a systematic way of increasing the training time and load as well as specificity of training was not always applied. The following rating scale reflects the investigator's perceptions of the overall degree of success in managing these factors for CS3 during the course of his preparation for Paralympic competition.

Direct Factor	Score*	Reasons
Performance Assessment	2	No specific goals for competition regarding placing or medals were set. Personal best performances were the most important. Not all laboratory assessments were completed fully and with enthusiasm. Problems motivating CS3 as well as a lack of cooperation from his coach, made it sometimes difficult to conduct the tests and to get CS3's full commitment. Testing after competition should be reconsidered due to lack of motivation.
Periodised Planning of Training	2	This is one of the factors that CS3 needs to improve if he wants to improve his performance. A great adaptation from the First to the Second and Third Macrocycle was made to improve time spent in the extensive aerobic zone, but adaptation of the programme closer to competition did not include higher intensity training as much as it should have during the last 6 weeks of training.
Feedback on Training	4	Feedback on training improved from Macrocycle One to Macrocycle Three. The use of training logs was not successful, but the heart rate training feedback was. Communication between the coach and the investigator as well as with CS3 was not always as it should have been. Contact through his father was made, who coordinates CS3's training.
Training Sessions	3	There was a greater emphasis on road training for CS3. An increase in track training resulted in a decrease of road training. More emphasis should be put on competing in races especially during the pre-competition phase, where no competition training is visible in the Third Macrocycle.
Training Camp	2	No true commitment to train with the squad.
Sports Medicine Services & Products	4	The support during the Third Macrocycle was good. It is suggested that CS3 should be able to benefit continuously from Sport Medicine Support.

* Rating scale from 1 (poor) to 5 (excellent).

Chapter Seven

Conclusions and Recommendations

This study focused on the preparation of three cyclists with cerebral palsy for the 2004 Paralympic Games in Athens. The specific intervention attempted was a system of sport science support described as sport performance management. The investigator served as the sport performance manager for these three cyclists for the 18-month period prior to their Paralympic competition. The broad research question that guided this study was:

Can a sport performance management system that targets selected direct factors, be implemented successfully with cyclists with cerebral palsy in their preparation for competition at the elite level?

The selected factors were:

- Performance assessment.
- Periodised planning of training.
- Feedback on training (training logs).
- Training sessions.
- Training camps.
- Sports medicine services and products.

Conclusions about the relative success of working with each direct factor are presented below. Thoughts about sport performance management specifically related to cyclists with cerebral palsy will also be provided.

Conclusions about the Direct Factors

Performance Assessment

All three cyclists completed their performance assessment tests on schedule as planned, and but only two of the cyclists appeared to be highly motivated. It can be concluded that performance assessment can be used successfully with elite cyclists with cerebral palsy as long as the cyclists are motivated to participate. Part of the job of the sport performance manager is to contribute to that positive motivation.

Despite the success of participation in the performance assessment tests, several considerations must be kept in mind by the sport performance manager:

1. Testing around competition time.

The three cyclists insisted that any testing close to a competition be scheduled after the competition. They all thought that if they had a poor performance on the performance assessment tests, it would have a negative psychological impact on their performance in competition. However, the motivation of the cyclists after the competition was perceived to be low.

2. The influence of the coach.

One coach complained that testing interfered with the training programme and requested the cyclist not to do the tests. The Paralympic Team required testing, so the cyclist actually had no choice. Fortunately, the relationship between this cyclist and the investigator was such that the performance assessments were a satisfactory experience. However, it must be noted that the support of coaches in performance assessment is very important. Many athletes admire and respect their coaches and if the coaches are not positive and do not see the use of performance assessment as information for planning training, the attitude of the athletes toward assessment will be negatively affected. This circumstance will undermine the validity of the testing process.

3. For able-bodied cyclists who can be tested and monitored over time in larger groups it is possible to follow changes in performance statistically. Therefore no subjective assessments of improvement or lack of improvement need to be made.

Also for laboratory tests using able-bodied cyclists many reports exist of the typical measurement error associated with each test. This is not the case for cyclists with cerebral palsy (disabilities). This made it difficult to determine whether or not an observed difference in test result was a significant change or not.

Certain considerations were included in this study that apply during the performance assessment of any athlete with cerebral palsy. These considerations include:

1. Determine each athlete's abilities and disabilities before the selection of tests.

Decisions about strategies and specific test protocols must consider the severity of the disability in the context of the abilities of the individual and the requirements of the sport (Goodman, 1998).

2. Even when the cyclist appears to be performing normal movement patterns during testing, their cerebral palsy is present and may be affecting their performance.

Involuntary movements, lack of muscle tone or excess tension may affect test performance and test results may vary from day to day (Goodman et al., 1998). Careful observation of the movement patterns of the athlete during testing is needed to form a picture of his/her motor coordination.

3. The performance assessment results of an athlete with cerebral palsy should be used to monitor his/her improvement and to set individual training goals.

Comparisons of performances between different individuals with cerebral palsy as well as between individuals with cerebral palsy and "able-bodied" peers, need to be treated critically and with skepticism (Goodman, 1998). Cerebral palsy is a disability with highly individualized consequences.

4. The members of the South African CP Paralympic cycling squad seldom race overseas and therefore the International ranking cannot be used as a measure of performance improvement. Similarly the races differ substantially in terms of race distance on the road, terrain and competitors vary from race to race.

Therefore race times are also not a true reflection of performance. For this reason only laboratory performance was considered.

Anthropometry

When making anthropometric measurements of individuals with cerebral palsy, it is important to use the non-affected side (if hemiplegic) for evaluations. The validity of using fat percentage norms and standard calculations needs to be questioned, due to the imbalance of muscle development, especially for athletes who are hemiplegic. Focus should be placed on individual improvements, although it has been found that there are no significant differences between sum of skinfolds for individuals with cerebral palsy and those without cerebral palsy (Winnick & Short, 1995). Pre- and post-intervention circumference measurements on both sides for hemiplegic athletes can help determine if the affected side has changed.

During the course of the study the three cyclists' anthropometry varied as follow:

- CS1: The sum of 8 skinfolds fluctuated with 10 mm, and his fat percentage ranged between 9.7 % - 11.7 %. No real differences in circumferences (arm flex, mid thigh and calf) were found.
- CS2: The sum of 8 skinfolds fluctuated with 9.8 mm, and his fat percentage ranged between 8 % – 9.6 %. His upper body circumferences (arm flex, arm relax, waist and hips) showed an increase from March 2003 to October 2003, with the increase in leg circumference not that much. This was during the time of the leg injury and CS2 spent a great deal of time in the gym, training his upper body.
- CS3: The sum of 8 skinfolds fluctuated with 15.2 mm, and his fat percentage ranged between 7.2 % - 9.9 %. CS3 achieved the same increase in upper body circumference as CS2, except that his increase was a systematic increase during the course of the study. These changes may have been related to age and maturation.

Incremental Exercise Test to Fatigue

The use of normative data from “able-bodied” cyclists should be used carefully because cyclists with cerebral palsy have a lower mechanical efficiency (Jones & McLaughlin, 1993), greater lactate concentrations at sub maximal workloads and higher heart rate values (ACSM, 1997). It is recommended that performances of persons with cerebral palsy should be measured against the person's previous results, and not against “able-bodied” norms (Goodman, 1998).

In this study, an interesting measurement from the incremental exercise test was the single leg power measurement. It was found that for all three cyclists, there was an improvement in efficiency as the workload increased. Not only did the weaker leg produce more power, but the negative resistant force decreased as well. This indicated that the cyclists were able to cycle more efficiently. These results suggest that by specifically training the pedaling action, the cyclist with cerebral palsy may be able to produce more power, not only by working harder with the weaker leg, but by reducing the resistance as well.

One concern that needs to be highlighted is that more work earlier in a race, might lead to earlier tiring of the more affected leg (due to neuromuscular fatigue). Another concern is that, while it appears that the weaker leg produced just enough power for initial test performance (and when really necessary the leg was able to produce more power), it is not certain that the leg would be able to sustain the higher power and efficiency for a longer period of time. Pedaling efficiency needs to be monitored as individuals due to the fact that the type and severity of cerebral palsy might influence the control over the motor patterns. The pedaling efficiency of CS3 was 97, with 100 as a perfect technique. This indicates that an excellent standard of pedaling efficiency can be achieved by some individuals with cerebral palsy. The weaker leg might be able to improve by doing various one leg exercises focusing on improving this aspect. This can be done by doing one leg cycling, single leg jumps or single leg weight training. There might be a good possibility for a learning effect that will improve performance.

All three cyclists achieved their best results on the incremental exercise test to fatigue during June/July, 2004. This was during the last macrocycle and in the build-up for the Paralympic Games. The decrease in values seen shortly after the Games is a point of concern, and may be a reflection of motivation as much as decreased post-competition training.

30-second Wingate Test

Peak sprint power is seen as a weak area for persons with cerebral palsy, due to the emphasis on the combination of strength and speed. Flescher (2002) noted the importance of intra- and inter-muscular coordination necessary for neuromuscular adaptations to develop power. Greater speed requires greater muscular coordination and this is a problem for individuals with cerebral palsy, who experience greater co-contraction of the muscle groups as the speed increases.

A great difference in mean sprint power values was recorded between the Division 4 (CS2 and CS3) cyclists and the Division 2 (CS1) cyclist. These results reflect the different types of cerebral palsy and demonstrate that the type of cerebral palsy may have an influence on the amount of power a cyclist is able to produce and sustain. The increase in peak sprint power for CS1 was 15 %. CS2 had a 10 % improvement if the July, 2003 testing is left out of consideration (his highest value was achieved in July 2003, after no

training), and CS3 had a 13 % improvement from April, 2003 to July, 2004. For both CS2 and CS3, their peak sprint power was less in October, 2004 than in July, 2004. Motivation might have played a role, or the drop in power it could have been the result of detraining.

1-Hour Distance Trial

Although time trials are often used as indicators of cycling performance, the 1-hour distance trial with the various hill climbs, has not been documented as a valid and reliable performance indicator. However, the test did provide important information regarding cadence selection on the hills as well as on the flats.

An optimal cadence is a cadence where the neuromuscular fatigue and the muscle force is minimized (Neptune & Hall, 1998). Optimal cadences for elite “able-bodied” cyclists were found to be 84 rpm on hills (Swain & Wilcox, 1992) and 90 rpm on the flats (Neptune & Hull, 1998; Hagbert et al., 1981), with 70 rpm the average cadence for recreation riders (Takaishi et al., 1996).

The average cadences of the three case studies over all tests for the 1-hour distance trial were:

- For the whole trial: 78 rpm for CS1, 87 rpm for CS2 and 74 rpm for CS3. This indicated quite a difference in cadence selection between the three cyclists.
- Average cadence for the 4 % incline during the 1-hour distance trial was 72 rpm for CS1, 82 rpm for CS2 and 70 rpm for CS3.
- Average cadence for the 8 % gradient hill was much lower with 61 rpm for CS1, 69 rpm for CS2 and 57 rpm for CS3.

A higher cadence selection places a higher demand on the physiological parameters such as the metabolic exchange ratio and lactate production (Hagberg et al., 1981). Jaone and McLaughlin (1993) stated that the mechanical efficiency of individuals with cerebral palsy is lower than that of their “able-bodied” peers. Optimal cadence selection for cyclists with cerebral palsy, therefore, is not simple because their lower mechanical efficiency at a higher cadence might lead to early fatigue. Investigations into how to determine optimal cadence under different road conditions are needed, but they will have

to be individualized. The variations in cadences chosen by the three case studies in this research indicated that each individual perceived a different cadence to be optimal for him.

What is the extent of the impact of cerebral palsy on the rate of neuromuscular fatigue that in turn influences the selection of optimal cadence? If optimal cadence minimizes muscle force, and the muscle force produced by the cyclist with cerebral palsy is less due to the effect of the cerebral palsy, then a higher cadence should be more beneficial. However, at what cadence will muscular co-contraction begin to have a negative influence, because faster leg speed required by the high cadence requires a higher level of muscular coordination?

A factor that also deserves more attention in future is the power output during the time trial. This may be more accurate than heart rate for determining intensity. Heart rate is known to be influenced by many factors such as temperature, state of hydration and high intensity training.

1 km and 3 km Time Trials

The results of the 3 km and 1 km time trials would have been of more value for performance management if power output could have been measured (Atkins & Brunskin, 2000). The greatest benefit of the time trials for the cyclists in this study was to determine gear selection based on the cadence each cyclist was able to maintain. The pacing strategies selected by each cyclist (either a fast start or a slow but sustained ride) could also be identified during the time trials. There was no option to change gears during a trial. In both tests, a higher cadence produced a faster speed. For both CS2 and CS3, their fastest 1 km and 3 km was achieved with their lowest gear selection.

Cycling at a fast cadence was first seen as problematic because coordination problems were anticipated due to co-contraction as a result of the cerebral palsy. However, a cadence of 115 rpm was easily maintained by both CS2 and CS3. CS3 was able to go up to an average of 130 rpm during his fastest 1 km time trial. For the cyclist with cerebral palsy, the possible impact of co-contraction at high cadence (negative affect) must be balanced against the realization that less power output is necessary to maintain the speed at higher cadence (positive affect). This makes selection of cadence a very individual decision. For some individuals with cerebral palsy, co-contraction will have a greater negative impact on the cycling pattern, and for others the fact that less power needs to be

produced might be beneficial. The significant correlation found for CS2 between cadence over the first 0.2km and 0.2-0.4km and average speed during the 1 km time trial, is indicative that a too big a gear, may lead to slower times. Due to the lack of power on the hemiplegic side, the bigger gear needs a greater amount of power to be generated. The time loss due to the slow start is difficult to make up during the race.

7.5 km Time Trial

Only CS1 did this time trial. The two best time trials were during March, 2003 and January, 2004. Both average heart rates were above 90 % of HR max, with the other trials showing lower heart rate intensity. Both trials indicated a high cadence at the start, lower steady cadence during the middle part and an increase in cadence towards the end. It is important to note that tactics and gear selection can play an important role in CS1's performance in the 7.5 km time trial (De Koning, 1999; Foster et al., 1993). The average cadence used during the 7.5 km time trial was 100 rpm. Research indicates that the optimal pedaling cadence is 90 rpm for trained cyclists during a longer stage race (Neptune & Hall, 1998; Hagbert et al., 1981).

Periodised Planning of Training

Periodisation of training should be one of the critical contributions that a performance manager could make to the preparation of any athlete for top-level competition. One limitation on periodisation in this study was the lack of competition training (lead-up competitions) before the main competitions. Inclusion in "able-bodied" cycling events is seen as the only practical approach to provide more competitive experience to cyclists with disabilities.

The investigator found it extremely difficult to influence the training plans of the three cyclists because of the coaching situation.

- CS1 had no coach and the investigator was directly involved in planning each day's training sessions. This made it possible to periodise training somewhat, although it must be acknowledged that a variety of circumstances made it difficult for CS1 to follow the plan every day.
- CS2 and CS3 both had coaches, and the coaches were only interested in looking at a general concept of phases and macrocycles. This minimal impact of any periodisation principles is an example of the importance of the interaction between the coach and the performance manager. A good working relationship is a vital part of performance management.

Attempts to periodise training did produce valuable information for future efforts to prepare cyclists with cerebral palsy. The training loads of each cyclist as well as the training volume, duration and intensity were presented in detail in the previous chapters. This is the first time this kind of detail appears in the disability sport literature. Previous research stated that persons with cerebral palsy fatigue easier due to a lower mechanical efficiency (Goodman, 1998). The training loads obtained by the cyclists in the study gives some indication of what training loads (volume, intensity and duration) are actually possible. This is not to suggest that the performances of the cyclists in this study be taken as norms for cyclists with cerebral palsy. Individualized interpretations of performance according to abilities and constraints of each individual will always be recommended (Goodman, 1998).

Feedback on Training (Training Logs)

Monitoring of training and the use of training logs were introduced to the cyclists in this study, for the first time in their career. All three regarded the completion of the training logs as a nuisance and did not appreciate the importance of keeping a training log. This meant that feedback regarding the specific focus of each days training was lacking. A more in-depth analysis of training could have been done if the cyclists had been willing each day to note the specific goal of a training sessions as well as the type of training session.

The introduction of the heart rate monitors made the feedback on training much easier and more interesting for the cyclists.

Training Sessions

The specific content of the training sessions for CS1 was planned by the investigator. For CS2 and CS3, the content of the training sessions was planned by their individual coaches. Goodman (1998) highlighted the importance of delaying fatigue for persons with disabilities by using intensity, duration, volume and rest periods in different combinations. The investigator did try to follow recommendations for several shorter sessions rather than one long session, stretching and relaxation between activities and good warm-ups, when planning CS1's training.

The modes of training used by the cyclists differed according to the availability of facilities. The modes of training used by CS2 and CS3 were the track, road and indoor

rollers. CS2 was also able to do regular gymnasium training. For CS1, the primary training mode was road and roller training, with spinning as another alternative especially when early sunsets and work commitments had an influence on available outdoor training time.

Although funding was available during the last macrocycle for hiring cycling facilities and access to a gymnasium, transport arrangements to the facilities were a problem for all three cyclists. The other problem area for them was time. None of them could train full-time, so there were days when they could not even find time for training on their bikes. Adding additional training to increase their workload was not an option.

Training Camps

The three cyclists in this study attended three training camps in the course of their preparation for the Paralympics.

- The first training camp was an introduction to the idea of having a performance manager, with special emphasis on explaining to them what a periodised training programme entails.
- The second training camp was an evaluation session by a qualified physiotherapist who had special expertise in cerebral palsy. This physiotherapist studied each cyclist's reflexes and the biomechanics of his seated position on the bi/tricycles. She made suggestions to each cyclist about subtle changes in his position. It is recommended that whenever bi/tricycles are built/adapted and a cyclist is trying to discover his/her optimal body position on the bike, that a person knowledgeable about cerebral palsy, reflexes and preferred body positions be consulted. The body position on the bi/tricycle for certain types of cerebral palsy will not always be the same as for "able-bodied" cyclists.
- The third training camp was the two-week residential camp that was with the Paralympic Team. CS1 and CS2 participated fully in the training camp, with CS3 participating where possible. CS3 did not participate fully. He said he would rather do some training with his own coach and training group on certain days and therefore did not attend all the training sessions. A second reason identified was his study commitments that interfered with the morning training

sessions. CS1 and CS2 reported that the training camp was beneficial for them. The fact that training was their main focus, with the support of a coach and no work commitments, made it successful.

Training camps are recommended as an important part of the sport performance management plan. For CS1, the third camp not only provided a break from work commitments, but also provided some quality coaching time, opportunities to ride in a group, and the time needed to train at longer distances. There are two major problems with training camps, however. They are expensive, so funding must be found. Some athletes have jobs and some employers are not supportive of the sport commitments of their employees.

Sports Medicine Services and Products

No money was available for sports medicine services and products for the first two macrocycles. During the Third Macrocycle, funding was available through Disability Sport South Africa (DISSA). Full medical screening and other sports medicine services were made available. It is recommended that sports medicine support needs to be available for a greater period of time. This conclusion is supported by the research completed by Rossouw (2001). Proper preparation does not start six months before a competition, but years before a competition. For individuals with cerebral palsy, and especially those with spasticity, massage and physiotherapy sessions will be beneficial. These kinds of interventions can help control spasticity, which will contribute to a greater ability to engage in demanding training sessions.

The cyclists got new bi/tricycles in the Third Macrocycle. This product support was appreciated and the cyclists did have some opportunity to training on the equipment before the Paralympics. It would have been more helpful to receive the new bi/tricycles at least one year before the Games.

Conclusions about Sport Performance Management and Individuals with Disabilities

Sport performance management is a multi-dimensional challenge. Even within the limitations adopted in this study, where only selected direct factors were worked with, it was an extremely difficult task. The ultimate goal of achievement at the Paralympic Games created pressure on the cyclists, the coaches and the investigator as their performance manager. The expectation for medals was always there, despite everyone's knowledge that performance on a given day depends on so many factors, including those beyond our control.

Performance management is about putting theory into practice. It requires subjective judgments and decisions based on a mixture of facts, logic and intuition. In addition to the normal demands of training experienced by their able-bodied peers, the cyclists in this study also required training advice that accommodated the impact of their cerebral palsy on their cycling. Additional problems are also introduced when one considers the following difficulties encountered by all athletes with disabilities in South Africa.

- Financial assistance is needed for athletes to pay for professional coaching and other sport science and sports medicine support.

In the South African Census of 2001 (A. Burchell, personal communication, October 21, 2004), it was reported that 2.25 million individuals are affected by disabilities. Of these persons, more than 1 million are not economically active. An additional 240 000 are currently unemployed. These individuals simply do not have the financial resources needed for serious training for sport.

A sustained high performance support and sport performance management programme is needed to support and guide the athletes. In the South African context, sport science and sports medicine support can play an educational and motivational role for athletes with disabilities, due to the lack of qualified coaches.

- Accessible transport and accessible training facilities are major problems. If athletes cannot get to training on a regular basis and/or cannot use a facility, they cannot prepare for top-level competition. The transport system in South Africa is not disability-friendly and this adds to the problem regarding transport experience by all athletes. The above-average unemployment rate among persons with disabilities leaves many athletes without the financial resources to public transport, even when it is available.
- The scarcity of qualified coaches who have a broad knowledge about disabilities and disability sport, is a special problem for athletes with disabilities. In those sports where South Africa has top coaches, few of them currently have training in working with athletes with disabilities.
- Opportunities for competition experience are limited at this time. Frequent competition in South Africa and internationally are important for physical and psychological preparation. Some sports in South Africa do include persons with disabilities in their “able-bodied” competitions and this does help competition preparation.

In an unpublished study by Crawford (2004), she highlighted the problems for selected elite athletes with disabilities in Kenya regarding their training practices and preparations. The major constraints were financial resources, lack of qualified coaching, inadequate facilities and training equipment and transport. The same situation exists in South Africa. Taking all these constraints into consideration, the fact that South Africa has finished 13th in the world in the 2000 and 2004 Paralympic Games, demonstrates the talent that exists. With a more systematic and scientific approach, it is possible that an even higher world ranking could be achieved.

Recommendations

The case study approach used by the investigator is recommended as a viable method for research on the topic of sport performance management, especially when the subjects have cerebral palsy. Cerebral palsy is a complex disability and each individual reacts in unique ways to different treatments and interactions in high performance training. The case study method requires that each subject be regarded individually and that his/her

performances be compared and interpreted in relation to his/her own abilities and disabilities. This focus on the individual makes it impossible to draw any firm conclusions about a population, however, implications for working with “similar others” can be drawn from the individual case and considered in future professional and research activities.

However, so little physiological exercise testing has been done around the world on CP cyclists that it is still unknown what the daily variation might be in test results without any change in training. It is recommended that base line testing should be performed twice within a short time period (less than 3 weeks) to determine how large a percentage change would need to be in response to a change in training for it to be considered significant.

Professional Implications

In terms of implications for sport performance management, the following implications have been drawn from this study.

1. A positive interaction between the sport performance manager and the coach is critical for success if performance management is going to be successful. Efforts must be made to make coaches feel part of the sport science and sports medicine team, and to include them in decision-making whenever possible.
2. It takes a lot of time to know a particular athlete, not just personally, but in terms of his/her training and competition preferences. Sport performance managers need to have that time to learn about each individual athlete, and to build an appropriate level of trust with him/her. For this reason, short-term applications of sport performance management systems are not recommended. This means that sport performance management will be expensive, since one manager can only work with a limited number of high-performance athletes, and the relationship will extend over a year or more.
3. A sport performance manager for cyclists with cerebral palsy must have an extensive knowledge base in both cerebral palsy and in cycling. The manager must have access to expertise in sport science and sports medicine, have sufficient experience to determine what services are appropriate at what time in the training year. Of course, funding must be available to deliver services to the

athlete. A weakness in any of these aspects of performance management will limit the manager's effectiveness.

4. As described earlier in the study, sport performance is the product of a combination of various factors, so it is difficult to highlight the influence of one training factor as being critical to success. In applied research such as this where the subject were striving to achieve Paralympic medals, it was the obligation of the performance manager to manipulate any training factor that might contribute to that goal. This is another reason why extended time for performance management is so important. It is not a single adjustment in training that will influence the result, but a collection of adjustments – some small and some large - from various areas in sports science and medicine, that will interact to make a positive contribution to the end product.

Implications for Research

Research in the field of sport performance management of elite athletes is difficult due to the great variety of influences influencing the end product. Controlling these factors is difficult because performance is so important. The following questions for future research about sport performance management and the preparation of cyclists with cerebral palsy have been drawn from the investigator's experiences during these case studies.

1. How can we determine the optimal cadence for a specific cyclist?
2. What factors should influence the decision about gear selection for track races?
3. How can the effect of training load on performance be monitored in a continuous way that is athlete-friendly?
4. What are the critical factors to consider when setting up the bike for a person with cerebral palsy and how will changes in the set-up influence performance?
5. To what extent can the pedaling action of a cyclist with cerebral palsy be improved?

Conclusions

Would the three cyclists in this study have performed as they did at the Paralympic Games, without the support of the sport performance management that was delivered to them for the 18 months prior to that competition? There is no objective way to be certain. In personal communication with the cyclists after the Games, they were asked to evaluate the effect of performance management on their performance in Athens. In this way, at least a subjective impression of the effectiveness of this study could be gathered. The cyclists were asked first to give an overall rating to the performance management effort, then make a comment to add detail to that rating. The following rating scale was used:

1	2	3	4	5
Not helpful	Somewhat helpful	Helpful	Very helpful	Essential

- CS1 rated sport performance management as having been “essential” to his preparation.

He attributed his performance to the Games in large part to the support he got from the sport performance manager.

- CS2 also rated sport performance management as having been “essential” to his preparation.

In his own words, “I wouldn’t have trained half as much as I did if it wasn’t for the support”.

- CS3 rated sport performance management as having been “somewhat helpful” to his preparation.

He stated that he found the testing was interesting, but that he needed more structured feedback and specific training programmes.

This feedback from the cyclists highlights the importance of individualization. The two cyclists who received more feedback and input into their training programme perceived performance management to have been essential for their preparation. CS3 received less input because he and his coach were not open for further input. The fact that CS3 felt that performance management was somewhat helpful underlines the need to establish positive working relationships with coaches.

The investigator rated her perceptions about the effectiveness of performance management in terms of the selected direct factors, on a 5-point scale at the end of each macrocycle. An average of the rating for each of the factors for each of the cyclists, is presented below:

Direct Factor	CS1	CS2	CS 3
Performance Assessment	4	4	2
Periodised Planning of Training	4.5	2	2
Feedback on Training	4	4	4
Training Sessions	4	3	3
Training Camp	4	4	2
Sports Medicine Services & Products	4	4	4
Total (30)	24.5	21	17

Comparing the perceptions of the investigator and the rating given by each cyclist regarding the effectiveness of sport performance management, there is agreement. The two cyclists who perceived sports performance management to be essential received the highest rating from the investigator.

Planning the training of an elite cyclist with cerebral palsy is a combination of art and science, with multiple factors influencing performance on any given day. Athletes train for years for that 0.1 second or 1 mm improvement that will mean the difference between winning and losing. This puts enormous pressure on athletes, coaches and supporting staff. The role of the performance manager should be to reduce some of the pressure put onto coaches and athletes, by advising them on how to combine a variety of training factors. This means that the performance manager will work in consultation with the different experts in sports science and sports medicine. In other words, it is the performance manager's job to bring the science of training to the athlete. In order to do

this job successfully, the knowledge base of the performance manager for cyclists with cerebral palsy, must include an understanding of:

- The classification system and the organization of cycling for persons with cerebral palsy.
- Characteristics of training for performance in cycling, as well as the influence of these training on the effect of cerebral palsy. It is important to identify when the intensity/volume/duration/frequency of training may have a negative interaction with the specific type of cerebral palsy of the specific cyclist. The severity of the disability will result in different abilities for each individual. It needs to be taken into consideration when planning the training programme.
- External problems that might affect a particular individual's training situation (such as financial factors, transport, personal behavior of the athlete, working commitments, facilities etc.) must be identified. The performance manager needs to take it into consideration that a particular cyclist's personal behavior might be influenced by his/her brain injury. Working commitments might have a more tiring effect on different cyclists with cerebral palsy and hard training sessions might be scheduled over weekends to ensure quality training. Training facilities, such as good roads for a tricycle to cycle, may be hard to find.

This study focused on the individualized management of selected direct factors important for sport performance for elite cyclists with cerebral palsy. The outcome of the study is a greater understanding of how selected direct factors can be manipulated to support the training of cerebral palsied cyclists. This study supports the words of Goldsmith (2001) that "performance is multifaceted and complex" and with the "combination of factors" the greatest contributor to performance (p.3). The question of "How to train for performance on a given day?" is relevant, but the answer is complex because it is so individualized. Using a framework that was successful for one athlete to guide the training of another athlete, might not produce the same level of success. Individualization is the challenge for the sport performance manager.

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Appendix A

Stellenbosch University Sport Science Center

CONSENT FORM

ATHLETE'S NAME..... DATE OF BIRTH:.....

SPORT:..... TEL:.....

ADDRESS:

PLEASE READ THE FOLLOWING CAREFULLY:

1. EXPLANATION OF HIGH PERFORMANCE TESTING PROCEDURE.

You will undergo a battery of tests to evaluate various physical and motor components associated with elite performance in your sport. The intensity of these tests will vary from comfortable to strenuous. The exercise tester may terminate testing at any point if s/he seems it necessary or appropriate. You may also stop the testing at **any time** if you feel uncomfortable.

2. RESPONSIBILITIES OF THE PARTICIPANT

Any information you possess about your health status, or previous experiences of unusual feelings with physical effort, may affect the safety and value of the testing procedure. Your prompt reporting of feelings with effort during the test are also of great importance. You are responsible to fully disclose such information.

3. RESULTS

The results from the different testing procedures can reveal some of your physical and motor strengths and weaknesses. In order to permit the tester to formulate a comprehensive program for improvement, your complete co-operation and compliance is essential.

4. CONFIDENTIALITY

The results from your tests are strictly confidential and only the testing center directly involved in the testing will have access to these records.

I hereby declared that:

- The testing procedures have been explained to me by the tester and I understand them.
- To the best of my knowledge I am currently free from any existing medical condition/other complaint or injury that would preclude me from full participation in the testing.
- I give my written consent to Stellenbosch Sport Science to conduct the battery of tests.



Appendix A

Stellenbosch University Sport Science Center

- I indemnify Stellenbosch Sport Science and the Stellenbosch Sport Science testers against any injury, death or damages which might stem from my participation in the testing.
- I give my consent for the results to be used for research purposes.

Athlete's signature:.....

Date:.....

Guardians signature(if under age of 18).....

Date:.....

Tester's signature:.....

Date:.....

Appendix B

PERSONAL INFORMATION SHEET

Name: _____ Surname: _____

Date of Birth: _____ Gender: _____

Address: _____

Telephone number: _____

Next Of Kin: _____

Contact Details next of kin:

ACADEMIC HISTORY

Highest Grade of Qualification: _____

Last School that you attended: _____

Higher Education (degrees etc): _____

Current occupation or study area:

Extra curricular activities at school:

MEDICAL HISTORY

Describe your disability in DETAIL (affected areas, coordination, motor control etc.):

Type of Cerebral Palsy according to motor control:

Ataxic		Spastic		Rigid	
Athetoid		Tremor		Mixed	

Type of Cerebral Palsy according to body areas affected:

Monoplegia		Diplegia		Hemiplegia	
Paraplegia		Triplegia		Quadriplegia	
Double Hemiplegia					

Classification:

Primary Classification _____ Sport Classification: _____

Describe your medical history during the following years (problems, rehabilitation like physiotherapy, occupational therapy, speech therapy, medicine etc.)

Years 0-7

Years 8-15

Years 15 till now

Allergies: _____

Medication: _____

Operations:

Injuries (current and previous):

SPORT HISTORY

Describe your sport history during the following years (all the sports you did, as well as anything you achieved in the sport)

Years 0-7

Years 8-15

Years 15 till now

When did you start training for cycling?

When did you start competing in cycling?

How many times a year do you compete intensively in a current year?

Describe your intensity during training:

What modes of training do you do - only on the bike or extra?

Is your bike setup specifically for you?

Do you have a coach - if yes who is the coach?

What expertise and qualifications does the coach has in cycling?

To what kind of facilities do you have access to - what distances do you need to travel to train?

Do you have a home trainer, heart rate monitor, any extra equipment?

What kind of access do you have to further professional / Sport science support?

Appendix C Cyclist's Training Log

General

Day:..... Date:.....
 Last night's bedtime:..... Hours Slept:.....
 Waking Heart rate:..... Heart rate 3 minutes later:.....
 Body weight:..... Feeling: tired/OK/energetic

Goals

Today's Training Goal

.....

.....

Today's Training

Injuries/sickness:

.....

Weather: cold / cool / windy / warm / excellent for training

Today's Training Session

Description	Total Distance		Total Duration
.....	Speed	Heart rate	Rating
.....	Minimum:	Minimum:	Easy
.....	Average:	Average:	Moderate
.....	Maximum:	Maximum:	Hard

Comments about the session:

.....

If no training - why not?

.....

Competition

Competition Results:

.....

.....