SPRINT ANALYSIS OF ATHLETES WITH INTELLECTUAL IMPAIRMENTS

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Declaration

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Abstract

Intellectually impaired (II) athletes are not allowed to participate at the Paralympic Games because there is no accepted classification system for these athletes. The rationale for this study was to see if there are any physical differences existing in the sprint performance of II and non-II athletes and to see if there is a way to incorporate these differences into a new (accepted) classification system.

The objective of this study was to identify any physical sources for the differences between II and non-II, with regard to the acceleration phase, the first 30m of the 60m sprint race, which could then be used in conjunction with other tests in the classification of II athletes. This new classification system might then allow II athletes to participate in the Paralympic Games again. 32 II athletes (22 male and 10 females) and 14 non-II athletes (10 males and 4 females) were used in this study. The sprint performance was analysed and compared of each athlete using the DartFish ProSuite software programme. The data collected from these analysis was then compared using the unpaired t-test, looking for any significant differences between the groups ($p<0.05$). From this analysis, it was concluded that stride length was the reason for the poorer performance of the II group when compared to the non-II group. Further research is required before definite conclusions can be made on the possible reasons for this difference.

Opsomming

Atlete met intellektuele gestremdhede neem nie deel aan Paralimpiese Speles nie omdat daar nie 'n aanvaarbare klassifikasiesisteem bestaan nie. Die rede vir hierdie studie was om vas te stel of daar enige fisieke verskille in die naelloop prestasie van intellektuele- en nie-intellektuele deelnemers bestaan. Indien wel, of hierdie verskille 'n bydrae kan lewer tot die daarstelling van 'n meer aanvaarbare klassifikasiesisteem.

Die doel van die studie was die identifisering van moontlike fisieke verskille tussen deelnemers met intellektuele gestremdhede en deelnemers sonder intellektuele gestremdhede gedurende die versnellingsfase (die eerste 30 meter) van die 60m naelloop-item. Saam met ander toetse kan die identifisering van moontlike verskille dalk 'n bydrae lewer tot die ontwikkeling van 'n nuwe sisteem en gevolglike her-toetrede van hierdie atlete tot Paralimpiese Speles.

Twee en dertig (32) atlete met intellektuele gestremdhede (22 mans en 10 dames) en 14 nie-intellektueelgestremde atlete (10 mans en 4 dames) het aan die studie deelgeneem. Om die naellooprestasie van elke deelnemer te ontleed en te vergelyk is die "DartFish ProSuite" sagteware program gebruik. Die inligting van hierdie ontledings is daarna vergelyk deur gebruik te maak van die ongepaarde t-toets om belangrike verskille ($p<0.05$) tussen die groepe na te gaan. Resultate hiervan lei tot die aanname dat treelengte die waarskynlike rede vir swakker prestasie deur die intellektueelgestremde deelnemers kan wees.

Verdere navorsing in hierdie area is egter nodig alvorens besliste gevolgtrekkings gemaak kan word.

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Chapter One

Setting the Problem

The 2000 Paralympic Games in Sydney marked a turning point in competitive sport for individuals with intellectual impairments. Spain was stripped of their goal medal in basketball when an undercover journalist playing on the team, revealed to media that most of his team-mates were not intellectually impaired. The International Paralympic Committee (IPC) investigated and found that the Spanish Paralympic Committee could not provide evidence that the appropriate IQ tests had been administered to their basketball players. Challenges regarding intellectual impairments were also made to the eligibility of some of the athletes on the Spanish table tennis, track and field, and swimming teams (CBC Sports, 2000).

The accusations of cheating have been described as one of the "most outrageous sporting moments in history" (Wikipedia, 2007). The situation led to an IPC announcement that it was immediately suspending all official sporting activities involving individuals with intellectual impairments at IPC events. The IPC cited serious problems regarding the determination of eligibility of athletes in making its ruling (New York Times, 2001; CBC Sports, 2000). On February 1st, 2003, the IPC announced that there would be no events involving athletes with intellectual impairments at the 2004 Summer Paralympics in Athens.

The continued suspension of these athletes from IPC competitions followed the failure of the International Sports federation for Persons with an Intellectual Disability (INAS-FID) to meet the conditions set by the IPC for establishing a revised system for the classification of athletes with intellectual impairments (INAS-FID, 2003). The IPC Management Committee recognized that some progress had been made by INAS-FID with regard to the development of a procedure to gather documents that supported the designation of an athlete as intellectually impaired. However, they also found that INAS-FID had not been able to develop a sport-specific component to determining eligibility or to design a system for the implementation of protest procedures in line with the IPC policy (INAS-FID, 2003). As yet, no changes have been made in the IPC position, which has created a gap in the opportunities for athletes with intellectual impairments to participate in top-level competitive sport.

Identification and Classification of Intellectual Impairments

It must be acknowledged that the task confronting INAS-FID is tremendous. The identification and classification of individuals with intellectual impairments is a multi-dimensional challenge. Children with intellectual impairment develop more slowly than children with average intelligence. The common description of intellectual impairment includes descriptions of the following characteristics (CDC, 2005):

- Failure to adapt normally and grow intellectually. In the case of mild impairment, difficulties may not become recognizable until school age or later.

- Failure to achieve other developmental milestones. An assessment of age-appropriate adaptive behaviours can be made by the use of developmental screening tests, but a low score must not be taken as proof of impairment. The observation of developmental lags in motor skills, language skills, and self-help skills compared to a child's peers are also indicators, but not proof, of impairment (AAMR, 2002).

There are different degrees of intellectual impairment, ranging from mild to profound. A person's level of intellectual impairment can be defined by their intelligence quotient (IQ) as measured by an individually administered intelligence test, and by the types and amount of support they need. The most widely used classification method consists of four levels of intellectual impairment according to the range of IQ scores as shown in Table 1 (Batshaw, 1997).

Table 1

The relationship between IQ scores and four levels of intellectual impairment

Level	**Intelligence Test Score**
Mild impairment	50-55 to approximately 70-75
Moderate impairment	35-40 to 50-55
Severe impairment	20-25 to 35-40
Profound impairment	Below 20-25

To confound the problem further, many individuals with intellectual impairments have other disabilities as well. Batshaw (1997) stated that common coexisting conditions include cerebral palsy, seizure disorders, vision impairment, hearing loss and attention-deficit/hyperactivity disorder (ADHD). Typically, children with severe intellectual impairments are more likely to have additional disabilities than are children with mild intellectual impairments.

The incidence of individuals at each of the four levels was estimated in the Diagnostic and Statistical Manual of Mental Disorders (DSM-IV) (DSM-IV, 1997):

1. Approximately 85% of persons with intellectual impairments are in the mild impairment category. Their IQ score ranges from 50-75, and they can often acquire academic skills at the level of the "average 12 year old." They can become fairly self-sufficient and, in some cases, live independently with community and social support.

2. Approximately 10% of persons with intellectual impairments are categorized as moderately impaired with IQ scores ranging from 35-55. They can carry out work and self-care tasks with moderate supervision. They typically acquire communication skills and are able to live and function successfully in a supervised environment such as a group home.

3. Approximately 3-4% of persons with intellectual impairments are severely impaired with IQ scores of 20-40. They may master very basic self-care skills and some communication skills. They may be able to live in a fully-supervised group home.

4. Only 1-2% of persons with intellectual impairments are classified as profoundly impaired with IQ scores under 20-25. They may be able to develop basic self-care and communication skills with appropriate support and training, but require a high level of structure and supervision. Their impairment is often caused by an accompanying neurological disorder.

The value of these levels are that they emphasize an assessment of the degree of impairment, recognizing not only is there a wide range in terms of impairment, but also in the kinds of interventions and amount of supervised care required to achieve individual potential (Murphy, Boyle, Schendel, Decouflé, Yeargin-Allsopp, 1998). The American Association on Mental Retardation (AAMR) has developed a comparable classification system for individuals with intellectual impairments that is focused on the capabilities of the individual rather than on their limitations. This system includes (AAMR, 2002):

1. Needs intermittent support.

2. Needs limited support.

3. Needs extensive support.

4. Needs pervasive support.

Intermittent support, for example, is support needed only occasionally, perhaps during times of stress or crisis. It is the type of support typically required for most mildly impaired individuals. At the other end of the spectrum, pervasive support, or life-long, daily support for most adaptive areas, would be required for individuals with profound impairments (AAMR, 2002).

Epidemiology of Intellectual Impairments

Most intellectual impairments are caused by multiple factors that may be of biological and/or environmental origin (Sherrill, 1998). The variety of factors that may influence the incidence of these impairments has been affected by changes in the definition of the impairment. The theoretical approach has typically supported use of the normal bell curve to estimate the number of individuals whose IQ falls below the established criterion score. For example, 2.3% of the population of the United States had an IQ score below 70, and 5.5% had an IQ score below 75 (McLaren & Bryson, 1987). In a more recent study conducted by the Centre for Disease Control (CDC), it was found that in the United States, approximately 1% of children ages 3-10 years had an intellectual impairment, that intellectual impairments were more common in older children (ages 6-10 years) than in younger children (ages 3-5 years), and that it is also more common in boys than in girls, and more common in black children than in white children (CDC, 2005).

Although the possible causes of intellectual impairments receives more attention in the next chapter, it is important to appreciate that the lack of understanding of what causes these impairments has also made it difficult to detect with certainty who has an impairment, especially in the category of mild intellectual impairments. If an individual does indeed have a score below 70-75 on an IQ test, does this necessarily mean that his/her functional ability in a sport will be affected? This is a simple way of stating the challenge put to INAS-FID by the IPC:

- Develop a system in which an individual can be identified as having a functional impairment that impacts on his/her sport performance in such a way that a separate class of Paralympic competition is warranted, and
- Develop a system that is sufficiently sport-specific so that it can be applied at an event should a protest be lodged about the classification of that athlete for participation in that particular sport.

Purpose of the Study

The general purpose of this study was to gain insight into the ways in which an intellectual impairment may affect sport performance. The specific purpose of this study was to contribute to the understanding of the possible ways in which an intellectual impairment (II) might impact on athletes' performances in sprinting. The strategy for fulfilling this purpose was to look at the similarities and differences in the sprinting mechanics of elite intellectually and non-intellectually impaired athletes.

Research Questions

The study was designed to determine if kinematic differences occur between intellectually and non-intellectually impaired (non-II) athletes. This question will be addressed over the first 30m of a 60m sprint racing which involves a crouched start. The following research questions were developed to guide this investigation:

1. What are the similarities and differences in the sprinting kinematics between II athletes and non-II athletes for the first seven strides of the acceleration phase of a 60m sprint (from the start to approximately 10m for the non-II athletes)?

2. What are the similarities and differences in the sprinting kinematics between II athletes and non-II athletes from the 10m point for the next four strides of the acceleration phase of a 60m sprint (approximately the second 10m for the non-II athletes)?

3. What are the similarities and differences in the sprinting kinematics of II athletes and non-II athletes from the 20m point for the next three strides (approximately 10m for the non-II athletes)?

Significance of the Study

Developing a valid and reliable classification system for athletes with intellectual impairments is a difficult and challenging task. INAS-FID has been struggling in their attempt to develop a more reliable and widely accepted classification system (INAS-FID, 2003). This study will use sport technology to analyse the movement mechanics of elite athletes with intellectual impairments to athletes without intellectual impairments in order to identify scientifically the differences and similarities between their performances. If there are differences, those differences may help to identify new criteria for the classification of athletes with intellectual impairments according to their movement patterns. If successful, this study also may help develop a reliable methodology for dealing with protests lodged at competitions about eligibility for participation in sprint events, since athletes with intellectual impairments would manifest certain movement mechanics in their sprinting performances. With such a methodology in place, the road back into Paralympic and other elite competitions may be sooner rather than later, at least for sprinters with intellectual impairments.

Methodology

A comparison was made between nine key kinematic variables that are manifested in performance of sprint events. The sprint performances of 32 athletes with intellectual impaired athletes and 14 non-intellectually impaired athletes were analyzed and compared. Unpaired t-tests were then used to identify any significant differences between the groups.

Limitations

This study was conducted as part of a more comprehensive multi-sport project conducted at an international event. This means that the investigator had to accept the constraints determined by the project organisers. These constraints included the number of cameras and their position in relation to the sprinters and the selection of athletes. The investigator also was unable to ask for additional information from any of the subjects, such as training age, access to coaching and regular competition, etc.

The opportunity to record large quantities of data on the sprinting of elite athletes with intellectual impairments was considered to outweigh these limitations.

Terminology

Intellectual Impairment

There have been numerous definitions of an intellectual impairment over the past years. One of the most commonly used was adopted in 1992 by the American Association on Mental Retardation (AAMR). It defined intellectual impairment as a substantial limitation in present functioning, characterized by significantly sub-average intellectual functioning. Intellectual impairments normally manifest before age 18, and exist concurrently with related limitations in two or more of the following adaptive skill areas (AAMR, 1992):

Communication.

Self-care.

Home living.

Social skills.

Community participation.

Self-direction.

Health and safety.

Functional academics.

Leisure.

Work.

Five assumptions are essential to the application of this definition (AAMR, 2002).

1. Limitations in present functioning must be considered within context of community environments typical of the individual's age peers and culture.

2. Valid assessment considers cultural and linguistic diversity as well as differences in communication, sensory, motor, and behavioural factors.

3. Within an individual, limitations often coexist with strengths.

4. An important purpose of describing limitations is to develop a profile of needed supports.

5. With appropriate personalized supports a sustained period, the life functioning of the person with the intellectual impairment generally will improve.

It is very important to remember that there is as much diversity of characteristics, abilities, and needs among people with intellectual impairments as there is within the general population. The AAMR (2002) on intellectual impairments said:

> Intellectual impairment is not something you have, like blue eyes or a bad heart. Nor is it something you are, like short or thin. It is not a medical disorder or a mental disorder. It is a particular state of functioning that begins in childhood and is characterized by limitations in both intelligence and adaptive skills. Intellectual impairment reflects the "fit" between the capabilities of individuals and the structure and expectations of their environment. (no page number)

Learning Disability

A learning disability is not the same condition as an intellectual impairment, although persons with intellectual impairments do have difficulty learning. According to the American Heritage Dictionary (2005), learning disabilities refer to a number of disorders which may affect the acquisition, organization, retention, understanding or use of verbal or nonverbal information. These disorders affect learning in individuals who otherwise demonstrate at least average abilities essential for thinking and/or reasoning

Learning disabilities result from impairments in one or more processes related to perceiving, thinking, remembering or learning. These include, but are not limited to: language processing, phonological processing, visual spatial processing, information processing speed, memory, attention, planning and decision-making. Learning disabilities may also involve difficulties with organizational skills, social perception and social interaction (Learning Disabilities Association of Canada (LDAC), 2002).

Learning disabilities are due to genetic and/or neurobiological factors or injury that alters brain functioning in a manner which affects one or more processes related to learning. These disorders are not due primarily to hearing and/or vision problems, socio-economic factors, cultural or linguistic differences, lack of motivation or ineffective teaching, although these factors may further complicate the challenges faced by individuals with learning disabilities. (LDAC, 2002).

From these descriptions, it is easy to see how some individuals with learning disabilities may appear to have an intellectual impairment. This adds substantially to the challenge of classification and underscores the importance of finding sport-specific evidence of the impact of intellectual impairments on performance.

Chapter Two

Review of Literature

The first section provides a brief overview of the behavioural characteristics of individuals with intellectual impairments. The second section provides a closer focus on what research has revealed about intellectual impairments participation in physical activity, with the third section providing a summary of current professional recommendations for coaches who work with individuals with intellectual impairments. The final section shifts the focus of the chapter away from intellectual impairments in order to examine sprinting, the specific skill performed by the subjects in this study. This chapter concludes with a summary of the characteristics of persons with intellectual impairments found in the literature that might affect their sprint performance.

Causes of Intellectual Impairments

Murphy *et al.* (1998) stated that the specific cause for an intellectual impairment is determined in only approximately 25% of the cases. They sorted the causes of intellectual impairments into nine categories:

1. Unexplained cause.

   This category accommodates the largest number of individuals for whom the causes of their intellectual impairments remain unknown.

2. Trauma.

   Injury to the brain can happen before or after birth. Examples of this include:

   - Intracranial haemorrhage before or after birth.
   - Lack of oxygen to the brain before, during, or after birth.
   - Severe head injury.

3. Infections.

   Infections affecting the brain can be present either at birth or occur after birth.

4. Chromosomal abnormalities.

   - Errors of chromosome numbers (such as Down's syndrome).
   - Defects in the chromosome or chromosomal inheritance.
   - Chromosomal translocations.
   - Chromosome deletions.

5. Genetic abnormalities and inherited metabolic disorders.

6. Metabolic abnormalities.

7. Toxic causes.

   - Intrauterine exposure to drugs, for example alcohol.

8. Nutritional causes.

   - Malnutrition

9. Environmental causes.

Severe Intellectual Impairments

The most common factor associated with a severe intellectual impairment has been chromosomal abnormality (*e.g.,* Down's syndrome). In approximately 20% to 30% of the individuals identified with severe intellectual impairments, the cause has been attributed to prenatal factors, such as chromosomal abnormality. Perinatal factors such as perinatal hypoxia account for about 11%, and postnatal factors such as brain trauma account for 3% to 12% of cases. This means that in 30% to 40% of all cases, the cause for a severe intellectual impairment is reported to be unknown (McLaren & Bryson, 1987).

Mild Intellectual Impairments

The incidence of mild intellectual impairments is not documented that well. Between 45% and 63% of the cases are attributed to unknown causes. Fewer cases of prenatal and perinatal causes are reported, with the largest number attributed to multiple factors (prenatal) and hypoxia (perinatal). Very few postnatal causes have been linked to mild intellectual impairments (McLaren & Bryson, 1987).

Assessment of Intellectual Impairments

Assessment is the systematic use of direct as well as indirect procedures to document the characteristics and resources of an individual (Simeonsson & Bailey, 1992). The process may be comprised of various procedures and instruments resulting in the confirmation of a diagnosis, the documentation of developmental status and/or the prescription of intervention/treatment. The assessment of a child suspected of having an intellectual impairment, may establish whether a diagnosis of intellectual impairment or some other developmental disability is warranted. Eligibility for special educational services, and/or aid in determining the educational or psychological services needed by the child and family is dependent upon the outcome of an assessment process. At a minimum, the assessment process should include an evaluation of the child's cognitive and adaptive or everyday functioning including behavioural concerns, where appropriate, and an evaluation of the family, home, and/or classroom (Sattler, 1992).

Sattler (1992) acknowledged that a variety of assessment instruments have been criticized for insensitivity to cultural differences that may have led to the misdiagnosis or mislabelling of some individuals. He noted, however, that assessments have many valid uses. For example, they allow for the measurement of change and the evaluation of programme effectiveness. Standardized instruments provide information about developmental levels.

It is clear that it is important to understand assessment and its purpose so that the tools which are available can be used correctly, and the results can be interpreted in a valid way (Sattler, 1992). Four types of assessment were identified by Sattler (1992) as appropriate for the evaluation of individuals suspected of having intellectual impairments:

1. Norm-referenced tests.
2. Interviews.
3. Observations.
4. Informal assessment.

These types of assessment complement each other and provide more complete information for making decisions about a child, including the biological, cognitive, social and interpersonal variables that affect the child's current behaviour. In the diagnostic assessment of children, it is also important to obtain information from parents and other significant individuals in the child's environment. For school-age children, teachers are an important additional source of information. Certainly, major discrepancies among the findings obtained from the various assessment procedures must be resolved before any diagnostic decisions or recommendations are made. For example, if the intelligence test results indicate that the child is currently functioning in the intellectually impairment range, while the interview findings and adaptive behaviour results suggest functioning in a average range, it would become necessary to reconcile these disparate findings before making a diagnosis (Sattler, 1992).

Intervention Programmes

The primary goal of behavioural intervention programmes is to develop each person's potential to the fullest. Special education and training may begin as early as infancy if the capacity for diagnosis and the resources for support are available. The success of these interventions is related to the aggressiveness of treatment, personal motivation of the participant, opportunities for sustained involvement, and many other factors. Many people are able to learn to lead productive lives while functioning independently, while others require a structured environment to be successful (Murphy *et al.*, 1998).

Prevention techniques aimed to decrease the incidence of intellectual impairments can be regarded as intervention efforts. Some of the commonly used techniques include (Rauch, 2005):

- Genetic interventions.

  These interventions include prenatal screening for genetic defects and genetic counselling for families at risk for known heritable disorders can decrease the incidence of genetically caused intellectual impairments.

- Social interventions.

  Government programmes to ensure adequate nutrition is available to the underprivileged in the first and most critical years of life can help reduce impairments associated with malnutrition. Social programmes to reduce poverty and provide education can impact the mild impairments associated with low socioeconomic status. Early intervention in situations involving abuse and deprivation will also help.

- Environmental health and safety interventions.

  Programmes to reduce exposure to lead, mercury, and other toxins will reduce toxin-associated intellectual impairments. However, the benefits may take years to become apparent. Increased public awareness of the risks of alcohol and drugs during pregnancy can help reduce the incidence of impairments.

- Public health interventions.

  The prevention of diseases such as congenital rubella syndrome is probably one of the best examples of a successful programme to prevent one form of intellectual impairment. Constant vigilance for proper health during pregnancy will help to reduce intellectual impairment that results from infection.

Intellectual Impairments and Behaviour

Batshaw and Perret (1992) observed that there are more differences between people with intellectual disabilities than there are similarities. The only common impact on behaviour appears to be a slower rate of learning than average for age. Intellectual impairments are most often associated with difficulties in information processing. Kozma and Stock (1993) stated that intellectual impairments are manifested as problems with attention, memory, abstract thinking, problem solving, and generalisation skills. According to these authors, the weakest areas of processing for persons with intellectual impairments are:

- Abstract thinking – the ability to grasp concepts and processes that cannot be directly experienced through the senses.

- Generalisation – the ability to apply what has been learned to new situations.

Umansky and Hooper (1998) agreed and added that problems with memory and attention are the most common difficulties that affect learning and the daily functioning of people with intellectual impairments.

In addition to information processing difficulties, Batshaw and Perret (1992) noted the following additional factors will impact on the behaviour of persons with intellectual impairments:

- The personality traits of the individual, such as temperament and motivation.
- The co-existence of any additional disability, such as cerebral palsy or epilepsy.
- Any medical circumstances, such as cardiac problems that could cause persistent fatigue and/or slow the rate of motor development, middle ear infections that can affect balance, causing particular difficulties for a child who is at the stage of learning to sit, stand or walk. Hearing problems could contribute to delays in speech and language development.
- Multiple environmental variables that impact on the type and variety of stimulation provided to the individual. For example, parents and other carers can make a significant impact on the rate and quality of a child's development.

When one considers the variety of variables and factors that contribute to intellectual capacity, plus the additional complexity introduced when the interaction among them, it becomes clear why there is so much difficulty surrounding definitions and descriptions of the impact of intellectual impairments on behaviour. This complexity also explains why it is currently impossible to predict the developmental potential of a person with an intellectual impairment (Batshaw & Perret, 1992).

Behavioural Symptoms

Individuals with intellectual impairments vary greatly in their observable behavioural symptoms. This variety is relative to the degree of their impairments as well as the social and environmental support they have experienced during their development. Batshaw (1997) found that the majority of individuals with intellectual impairments display the following behavioural symptoms, at least to some degree:

1. Failure to meet intellectual developmental markers.
2. Persistence of infantile behaviour.
3. Lack of curiosity.
4. Decreased learning ability.
5. Inability to meet educational demands of school.

Murphy *et al.* (1999) added that difficulties in normal adaptive behaviours in daily living depend on the severity of the condition. Mild intellectual impairments are often associated with a lack of curiosity and quiet behaviour, while severe intellectual impairments may be associated with more infantile behaviour throughout life. The impact of more severe intellectual impairments have been observed to affect other aspects of daily living, manifested as social isolation, inability to care for self and inability to interact with others appropriately (Murphy *et al*., 1998).

Intellectual Impairments and Physical Activity

Increasing concern has been expressed about mortality, morbidity and the behavioural determinants of health among people with intellectual impairments (Prasher & Janicki, 2002; Sutherland, Couch & Lacono, 2002; Walsh & Heller 2002). Significant deviation from normal weight (either obesity or underweight) and lack of physical exercise have been identified as significant global behavioural risks to health world-wide (World Health Organization (WHO), 2002). The available evidence does suggest that people with intellectual impairments may be at an increased risk for each of these three behavioural determinants of physical ill-health (Emerson, 2005). For example, approximately 20% of the adults with intellectual impairments have been classified as obese with a strong inverse relationship between intellectual impairment and adiposity (Hove, 2004).

The above mentioned is not a current trend. In his summary of research completed before 1970, Rarick (1973) concluded that intellectual impairments are almost invariably accompanied by substandard levels of physical and/or motor performance. According to Rarick (1973), adolescents with mild intellectual impairments lagged 2 to 4 years behind their age-peers without intellectual impairments on measures of physical and motor performance. Cognitive delays associated with intellectual impairments may influence reaction time, acquisition of fundamental motor patterns, physical fitness and complex motor skill development (Shapiro & Dummer, 1998).

Physical Fitness

In general, studies have reported that individuals with intellectual impairments generally demonstrate poor fitness levels on standard fitness tests. This has included the variables of cardiovascular endurance (Fernhall & Pitetti, 2001), body composition (Rimmer, Braddock & Fujiura, 1993) and muscular strength and endurance (Mac Donncha, Watson, McSweeney & O'Donovan, 1999; Horvat, Pitetti & Croce,1997). Percentage body fat for both male and female athletes with intellectual impairments was found to be 3–4% higher than the standards for percent body fat for young active non-intellectually impaired adults (10% body fat for men; 23% body fat for women) (Lohman, Houtkooper & Going, 1997).

Young adults with an intellectual impairment (20–30 years of age) typically exhibit cardiorespiratory fitness levels that are 8–12% lower than expected values (Pitetti, Yarmer & Fernhall, 2002; Fernhall, Pitetti, Rimmer, McCubbin, Rintala, Miller, Kittridge & Burkett, 1996), and show peak heart rates to be lower by about 15 beats/min compared with their peers without an intellectual impairment (Fernhall & Pitetti, 2001). The cardiorespiratory endurance of elite athletes with intellectual impairments was found to be poor compared to physically active non-intellectually impaired individuals, all of whom participated regularly in sport, but not necessarily at a high-performance level (Stickland, Petersen & Bouffard, 2003). Physical work capacity, as measured by run performance, is lower in adolescents with an intellectual impairment when compared to their non-impaired counterparts (Pitetti & Fernhall, 2004).

Comparison of the strength of elbow and knee extension and flexion between young adults with intellectual impairments and sedentary, non-intellectually impaired individuals showed 35–40% lower strength levels for individuals with mild intellectual impairments (Pitetti & Yarmer, 2002; Horvat *et al.*,1997). One of the few longitudinal studies focused on the physical fitness of adults with intellectual impairments was carried out by Graham and Reid (2000). The Canadian Standardized Test of Fitness was used to assess 32 participants with mild and moderate intellectual impairments: 14 women and 18 men, aged 34-57 in 1983 and again 13 years later in 1996. The physical fitness of these adults with intellectual impairments was initially lower than for the non-intellectually impaired adults, and their fitness declined over time. In addition, the magnitude of change over years, as compared to the participants without an intellectual impairment, was significantly greater for both males and females in body mass index (BMI).

Not all results from the research are negative. According to Lefevre, Philippaerts, Delvaux, Thomis, Vanreusel, Vanden Eynde, Claessens, Lysens, Renson and Beunen (2000), the physical fitness status of the athletes with intellectual impairments that they tested was better than that of a mixed group of individuals without impairments (including individuals with lower activity rates) on the fitness variables of flexibility and upper body muscle endurance. For the variables abdominal muscle endurance and running speed, athletes with intellectual impairments did not score better that the non-intellectually impaired subjects. They scored lower than individuals without intellectual impairments on the variables of speed of limb movement, explosive strength and handgrip strength.

Frey, McCubbin, Hannigan-Downs, Kasser and Skaggs (1999) found in their research that individuals with intellectual impairments had high levels of cardiovascular fitness, similar to those of active individuals without intellectual impairments. This finding led them to challenge the perception that persons with intellectual impairments are unable or unwilling to participate in physical training of sufficient frequency, intensity and duration to elicit high levels of fitness.

A recent study by Van de Vliet, Rintala, Frojd, Verellen, Van Houtte, Daly, Vanlandewijck (2006) assessed the fitness level of high-performance athletes with intellectual impairments and compared their performances to standards for non-intellectually impaired individuals. A total of 41% of the participants at the 2004 International Sports Federation for Persons with Intellectual Disability (INAS-FID) Global Games volunteered to take a physical fitness test battery. The authors contended that this sample could be considered representative of the INAS-FID athletes competing at world level in athletics, basketball, football (males), table tennis, tennis, and swimming. They found that the athletes with an intellectual impairment met a high-standard of performance-related criteria in their sport. When they compared the physical fitness profile of athletes with intellectual impairments to athletes without, the INAS-FID male athletes scored better for flexibility and running speed, but had lower strength and muscle endurance levels. Their female INAS-FID athletes had similar levels of flexibility, upper body muscle endurance and running speed as non-intellectually impaired athletes, but had lower explosive and hand-grip strength levels and lower abdominal muscle endurance.

Motor Skill Performance

Researchers comparing motor performance of individuals with an intellectual impairment to those without have consistently reported lower levels of motor proficiency for individuals with intellectual impairments (Dobbins & Rarick, 1977; Londeree & Johnson, 1974). The reasons for these levels have not been discovered. For example, in a study conducted by Hoover and Wade (1985), it was found that once skills and movement combinations are in the long-term memory of a individual with an intellectual impairment, their forgetting rate is no faster than that of non-intellectually impaired individuals.

There are two variables, however, that impact on sprinting performance and are reported in the literature - balance and reaction time.

Balance

When growth and development conditions are “normal,” children will develop sufficient balance and successfully attain various skills. However, when impairments in development of an individual exist, such as an intellectual impairment, development of ‘normal’ balance may not be possible (Rider & Abdulahad, 1991).

Balance is classified in two ways (Rider & Abdulahad, 1991):

1. Dynamic balance.

   This refers to the ability to control the relationship between the body’s centre of gravity and a base of support which is moving from one position in space to another.

2. Static balance.

   This refers to maintaining the relationship of the centre of gravity over the base of support in a non-locomotor state. The development of static balance must begin before the development of dynamic balance.

Because the acquisition of motor proficiency relies on the development of static and dynamic balance control, it is not surprising that the motor skill development of many individuals with intellectual impairments lags behind the published standards for non-intellectually impaired individuals (Rider & Abdulahad, 1991). If motor skill experiences are limited during the key learning periods of childhood, it is not surprising that there will be limitations on the levels of motor proficiency attained in the teenage years and adulthood.

According to Di Rocco, Clark and Phillips (1987) children ages 4 – 7 with intellectual impairments lag behind non-impaired peers in terms of the development of their arm coordination for the standing long jump, although leg coordination develops at the same rate. The largest differences in performance were recorded in the distances jumped, with the children without intellectual impairments jumping two to three times longer. The authors observed that the differences in jumping distances may be an outcome of differences in balance control. They suggested that for children with intellectual impairments tipping forward to jump threatens balance to such an extent that it may cause hesitancy or braking actions in muscle synergies activated to perform the jump. They concluded equilibrium may act as a rate limiter on the performance of horizontal and/or vertical application of ground forces and suggested that research be focused in this direction.

Reaction Time

Research has attempted to identify why individuals with intellectual impairments generally do not meet the standards of motor performance achieved by non-intellectually impaired individuals (Kioumourtzoglou, Batsiou, Theodorakis & Mauromatis, 1994). In a study by Davis, Sparrow and Ward (1991), adults with intellectual impairments had slower reaction times than non-intellectually impaired individuals. Kioumourtzoglou *et al.* (1994) concluded that the slower reaction times of individuals with an intellectual impairment reflected their limited capacity to maintain appropriate attention. Hoover and Wade (1985) had previously warned against the assumption that individuals with intellectual impairments necessarily had difficulties with the control of attention. They cited research to support the position that individuals with intellectual impairments experience challenges in selecting and the performing responses, not in controlling their attention.

The Kioumourtzoglou *et al.* (1994) conclusion was in contrast to an earlier study by Wade, Newell and Wallace (1978) who also found that reaction times for individuals with intellectual impairments were considerably longer and more variable than those for non-impaired individuals. However, they suggested that information–processing differences in motor skills between the two groups could be attributed to response parameters, (*e.g.* speed of movement, its amplitude and the limb used). In fact, when Kelly, Barton and

Abernathy (1987) examined reaction times for fine and gross motor movements to light and sound stimuli of individuals with intellectual impairments, they found no significant differences when comparisons were made to non-impaired individuals. Care must be taken, then, in assuming that there is a difference in reaction time between individuals with and without intellectual impairments.

In the study conducted by Hoover and Wade (1985), it was found that if there was an added preplanning element prior to the movement (a decision needs to be made) that the performance was reflected by latencies. They concluded that the likely explanation for this is that when given the added choice component that intellectually impaired individuals were unable to preplan the movement, and therefore their reaction time was delayed, which was not seen in their non-impaired counterparts.

Practice and Motor Proficiency

There is controversy concerning the superiority of some schedules of practice over others in terms of effectiveness in learning motor skills. The impact of the distribution of practice on learning has provided a particular challenge to researchers (Lee & Genovese, 1988). Some authors have argued that massing of practice (*i.e.,* repetitions of a skill with minimal rest in between trials) can produce immediate gains in motor proficiency, but that these gains do no last when compared to the gains achieved through distributed practice (*i.e.,* repetitions of a skill with rest in between trials) (Rider & Abdulahad, 1991; Magill, 1985; Schmidt, 1975).

Magill (1985) took the position that that the massed versus distributed practice schedule controversy is best resolved when the type of skill is considered. Continuous skills such as running benefit from distributed practice because there are no natural breaks in the action, which means there is no opportunity for the brain to consolidate learning until performance stops. Discrete skills, such as putting a shot, should minimise rest periods in between (mass practice) since there are natural breaks in the action because the skill has a distinct beginning and end. Discrete skills should not be controversial at all and that distributed practice is superior with regard to performance during early acquisition. However, when the amount of learning is considered, the two practice schedules tend to be nearly equal (Magill, 1985). Magill (2003) noted that it is generally believed among physical educators that, when working with young learners or beginners, distributed practice tends to provide better results in learning new skills, and when teaching advanced and more highly skilled learners, massed practice should be the schedule of choice.

Although massed and distributed practices have received the most attention in efforts to enhance learning (Rider & Abdulahad, 1991), the early research findings of Willig and Ammons (1956) showed a lack of a distinct advantage of one schedule over the other in learning and retention for individuals with intellectual impairments. They suggested that this is likely because as practice continues, under either schedule, a reasonable level of proficiency is acquired.

Unfortunately, very little research in motor learning has been undertaken with individuals classified as intellectually impaired (Rider & Abdulahad, 1991). Perhaps many individuals with intellectual impairments could learn motor skills to similar levels of proficiency as non-intellectually impaired individuals, if the instructor was successful in controlling variables that might interfere with their motor learning. However, those variables are not known. For example, the more an individual is stimulated by the general environment, the less they may be able to attend to the task at hand, which would have a negative effect on learning. Conversely, an environment with little or no stimulation may lead to boredom, which would inhibit interest in the task and have a negative effect on learning (Rider & Abdulahad, 1991).

Consideration must be given to the effect of environmental demands on learning and motor performance (Distefano & Brunt, 1982). A skill executed under predictable environmental constraints is termed a “closed” skill. With repeated practice in an environment with minimal variations, consistency develops and performance level improves. However, many skills are not performed under such conditions and instead a response may have to be modified to cope with environmental stress or uncertainty. They are referred to as “open” skills. When practicing an open skill, variety in meeting the challenges of changing situational or environmental demands must be provided.

To emphasize the importance of recognising the difference between the demand of open versus closed skills, Distefano and Brunt (1982) devised a simple test in which the impact of environmental uncertainty on an individual’s running ability was assessed. Non-intellectually impaired individuals who had achieved constancy in running skills did not exhibit a change with increased movement uncertainty. However, individuals with intellectual impairments experienced deterioration in running skill performance.

Studies have been conducted to clarify the differences between learning characteristics of individuals with and without intellectual impairments. For example, Hirsch (1965) found that the part method of teaching works better with individuals with intellectual impairments, while non-intellectually impaired individuals seem to learn better under the whole-part format. Davis (1968) agreed that activities should be broken into smaller learning units for individuals with intellectual impairments, and that these units then gradually be incorporated into a final product. Drowatsky (1970) suggested that direct teaching methods and individualised instruction be used with such individuals with intellectual impairments.

Intellectual Impairments and Coaching

There may be a misperception that people with intellectual impairments who participate in sport are mostly children. While it is always important for coaches to focus on each athlete’s capabilities, age-appropriate activities are recommended. The Coaching Association of Canada (2005) manual stated that the specific skills required for a particular activity may have to be modified to meet an athlete’s developmental level:

> It is inappropriate to place adults with an intellectual disability in programs for children…Athletes with intellectual disabilities need to be placed in programs with peers of similar age. But at the same

> time coaches must be prepared to modify skills and drills to address developmental needs (Coaching Association of Canada, 2005:12).

Dino Pedicelli has been coaching athletes with an intellectual impairment for over 25 years. During this time, he has coached virtually all Special Olympics sports. According to him:

> These athletes must be treated the same way any other athletes of the same age would be. Adults must not be dealt with as though they were children…It is some times necessary for the coach to adjust, and to talk at a level they can understand, but this only means that instructions must be simple and clear (Coaching Association of Canada, 2005:10).

Repetition is a proven strategy for learning that is also effective with Special Olympics athletes. The cycle of “tell them, show them, help them and remind them” appears in the Special Olympics coaching guide. Coaches are warned, however, that there is no one strategy that works for everyone, and they will need to be creative and emphasize enjoyment in order to establish an optimal learning environment for athletes with intellectual impairments (Special Olympics Coaching Guide, 2003; Holland, Goodman & Walkley, 1994).

Recommendations for Coaching

According to the coaching association of Canada (Coaching Association of Canada, 2005), there are a number of recommendations for coaching athletes with intellectual impairments. These include:

- Plan drills/activities that are age appropriate.
- Teach the necessary prerequisite skills (*e.g.,* basic motor skills) first.
- Do not overload participants with instructions.
- Check regularly for understanding (athletes may take longer to process information or instructions).

- Coach the specific skill. Athletes with intellectual impairments may have difficulty transferring skills from one environment to another.
- Provide repetition, structure, and routine to support the athletes' memory.

Patterns of Coaching

While few would argue that Special Olympics program can benefit their participants, Special Olympic sport programmes (as opposed general physical activity programs) have been criticized for being insufficient to properly prepare athletes for competitions. As with many aspects of Special Olympics, there is little empirical evidence to either support or contest this contention. What is known suggests that the quality and frequency of training programmes experienced by athletes vary widely (Holland *et* al., 1994).

Miller (1987) surveyed 194 Special Olympic coaches in the United States (with a return rate of 88%) and reported that training usually began about eight weeks prior to the event at a rate of three to six total hours per week. Roper and Silver (1989) surveyed Special Olympic chapters in the United States and reported an equal distribution of groups who began their training zero to two, three to five, six to ten, and eleven months prior to the event. They further reported that, with some age-dependent variations, training was usually in the category of zero to three days per week. In almost 50% of all cases the sessions lasted one hour or less. Dahlgren, Boreskie, Dowds, MacTavish and Watkinson (1991) concluded that the lack of specificity and volume of practice for this group of athletes makes it very difficult if not impossible for them to perform at top levels.

The quality of coaching education background could be proposed as one reason for the inadequate practice schedules. However, the results of a recent survey as reported in Table 2 do not support this explanation (Research Report to IPC Governing Board, 2006).

Table 2

Levels of education among coaches of athletes with intellectual impairments

Level of Education	***% of all respondents***
Sports Science Degree	54%
National Sport Technical Certification	85%
Educational background in working with individuals with Intellectual Impairments	84%
Qualification in elite sport (non-disabled)	86%

In terms of coaching experience specifically with athletes with intellectual impairments, these same coaches reported their years of experience in a particular sport as presented in Table 3 (Research Report to IPC Governing Board, 2006).

Table 3

Years of experience coaching athletes with intellectual impairments

Years of Coaching Experience	**Athletics** n (%)	**Swimming** n (%)	**Table Tennis** n (%)
< 1 Year	8 (5%)	15 (14%)	4 (6%)
1 – 3 Years	60 (36%)	31 (28%)	19 (27%)
4 – 6 Years	64 (38%)	26 (23%)	24 (34%)
> 7 Years	37 (22%)	39 (35%)	24 (34%)
Total coaches per sport	**169**	**111**	**74**

The majority of coaches in this report were found to have between 1 to 6 years experience, and they had reasonable levels of education. Why the apparent lack of serious training for the athletes? Surely, lack of experience would lead to less productive practice session, but not necessarily to fewer sessions, scheduled just prior to events.

Hoover and Wade (1985) may have provided some insight into this situation when the examined the beliefs held how individuals with intellectual impairments process information when they learn and practice motor skills. They reported that the majority of scientists and educators operate under the assumption that there is some kind of information processing deficit associated with an intellectual impairment. This would lead to the conclusion that the individual can only progress to a certain level, and that the investment of training time and effort past that point will not produce any changes. The authors did not find sufficient evidence to support this assumption and challenged scientists and educators to consider the possibility that we simply have not yet found the optimal way to teach persons with intellectual impairments, because we have yet to identify the causes of their difficulties in learning, behaviour, etc. It is possible, they concluded, that the persons who work with individuals with intellectual impairments have accepted the deficit approach and therefore only expect a certain level of learning and achievement, rather than trying to find the key to understanding how to accelerate learning and raise levels of achievement.

The Sprint

The sprinting action requires fast reaction time, good acceleration and an efficient running style (Carr, 1991). In order to understand how the body moves in order to sprint, it is helpful to look at how the locomotor movement pattern changes between walking, running and sprinting. In Figure 1, a continuum is presented that shows the phase changes from standing still on one extreme to sprinting at the maximum speed on the other extreme (Novacheck, 1998):

- Standing still becomes walking when the walking gait cycle is initiated.
- The demarcation between walking and running is marked at Point A, when periods of double support during the stance phase of the gait cycle (both feet simultaneously in contact with the ground) shift to two periods of “double float” (neither foot is touching the ground), one period the beginning and the other at the end of the swing phase of the gait cycle. At point A, the stance is approximately 50% of the gait cycle.

- As the speed of the gait cycle increases, a point is reached (Point B) when the initial site of foot contact with the surface changes from being on the hind foot to the forefoot. This typically marks the distinction between running and sprinting.

Figure 1

Points of transition from walking to sprinting (Novacheck, 1998:78)

In athletics today, top level competitors sprint all distances from 100m up to 400m. Under the International Amateur Athletics Federation (IAAF) rules such races must start from a crouched position in blocks (Novacheck, 1998). Although running may be regarded as a fundamental locomotor skill, sprinting requires long hours of practice and substantial levels of fitness in order to master the technique. In order to approach training in a systematic way, Mann and Sprague (1983) divided the 100m sprint event into three phases:

1. Acceleration phase.
2. Maximal running velocity phase.
3. Deceleration phase.

Of these three phases, Mann and Herman (1985) identified the maximal running velocity phase is the best indicator of sprint success in the 100m event.

For sprinting, the body and its segments are moved as rapidly as possible throughout the entire race (Novacheck, 1998). Elite sprinters perform with a forefoot initial contact, and it is often the case that the hind part of the foot never contacts the ground. In order to gain an insight into the kinematics of the sprint, the sprint start, the sprint stride, and the optimal sprint will be described in the following sections.

The Sprint Start

At the start of a sprint race the starter gives three commands in order to start the race. These are "On your marks," "Set" and "Go" (or else a gun is fired). When the athlete hears the initial command, "On your marks", he/she moves forward and adopts a position with the hands approximately shoulder width apart and just behind the starting line. The feet are in contact with the starting blocks and the knee of the rear leg is in contact with the track. On hearing the "Set" command, the athlete raises the knee of the rear leg off the ground and thereby elevates the hips and shifts the centre of gravity up and out. This is the “Set” position. Then, on the command "Go" or when the gun is fired, the athlete reacts by lifting the hands from the track, swinging the arms vigorously whilst driving with both legs off the blocks and into the first running stride (Harrison & Comyns, n.d.).

Under the rules of the International Amateur Athletics Federation (IAAF) all runners/sprinters in races from 100m up to 400m must start from a crouched position in blocks (Novacheck, 1998). This means that the crouched start is a motor skill that must be learned by all sprinters. Magill (2003) defined a motor skill as a voluntary action that has a goal. Specifically, the sprint start is categorized as a gross, discrete, and closed motor skill (Magill, 1993). It is a gross skill because it involves whole body coordination of large musculature. It is considered a discrete skill because it has a definite beginning and it “ends” when the runner achieves an upright normal sprint stride position. It is a closed skill because the start is performed under relatively fixed and unchanging environmental conditions. Because it is performed so quickly, it is considered to be under open-loop motor control (there is no time to use feedback to make corrections during performance).

The crouched start position is more effective than a standing start because it places the sprinter in a position to move the centre of gravity rapidly well ahead of the feet, which means that the runner must accelerate very quickly or else fall (Adrian & Cooper, 1995). Movement from the “set” position in the sprint start must not only be fast and forceful but should permit the sprinter to rapidly move into a mechanically efficient running position (Harrison

& Comyns, n.d.). Although the start is a separate skill from sprinting, it is an integral part of all sprint events. Stampf (1957) commented that:

> The important thing is to reach top speed as quickly and smoothly as possible, and this can only be done if the rhythm of the stride begins actually in the starting blocks. (p. 53-54)

The three main types of crouched start positions are illustrated in Figure 2 (Hay, 1993):

1. The bullet start.

   The toes of the rear foot are approximately level with the heel of the front foot and both feet are placed well back from the starting line.

2. The medium start.

   The knee of the rear leg is placed opposite a point near the front half of the front foot.

3. The elongated start.

   The knee of the rear leg is level with or slightly behind the heel of the front foot.

(i) (ii) (iii)

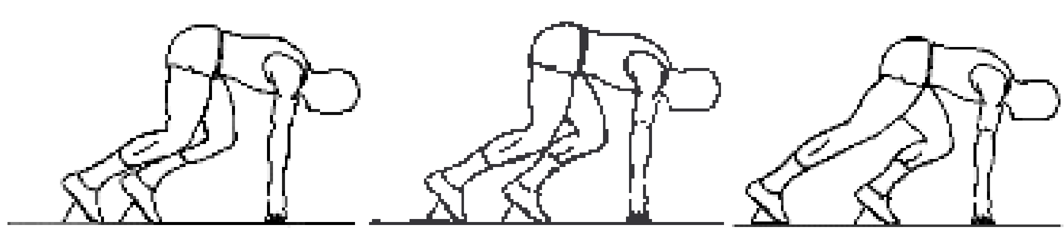

Figure 2

The (i) bullet or bunch start, (ii) medium start and (iii) elongated start (Harrison & Comyns, n.d.)

Early research suggested that the medium start offered the most advantages to the sprinter (Henry, 1952). This statement was based upon the rationale that when compared to other starts, the medium start allows the sprinter to exert a higher force against the blocks for the longest possible time, which produces the maximum impulse so that the athlete leaves the blocks with the greatest possible velocity. When the bullet start and the elongated start were compared, the bullet start was found to contribute to a faster time over the initial meters and yet slower over the entire distance, while the elongated start produced slower times over the initial meters of the race and faster times over the entire sprint distance (Mero & Komi, 1990; Henry, 1952).

The purpose of the sprint start is to facilitate an efficient displacement of the athlete in the direction of the run. It enables the sprinter to start the race with his/her body sloping as required for acceleration. Bunn (1955) stated:

> In starting, the emphasis is upon getting away from the mark as quickly as possible, and then into a position that will be favourable to developing the desired pace in the shortest distance (p.105)

If executed properly, the sprint start allows the athlete to leave the blocks balanced and with maximum velocity (Harrison & Comyns, n.d.). In order to accomplish this, the following objectives of the sprint start must be achieved:

1. To establish a balanced position in the blocks.
2. To obtain a body position where the centre of gravity is as high as is practical and slightly forward of the base of support.
3. To apply force against the blocks in a line through the ankle, knee and hip joints, the centre of the trunk and head.
4. To apply this force against the blocks and through the body at an angle of approximately 45°.
5. To establish the optimum knee joint angles in both the front and rear leg.

6. To clear the blocks balanced and with the greatest possible velocity.

Block acceleration is that phase of the sprint where the kinematic parameters of the sprint step change most dynamically (Čoh, Tomažin & Štuhec, 2006). Acceleration out of the blocks (block acceleration) is a complex cyclical movement defined predominantly by the following three parameters (Locatelli & Arsac, 1995; Mero, Komi, & Gregor 1992):

1. The progression of change in the frequency and length of steps.
2. The duration of the contact and flight phases of each step.
3. The position of the body's centre of gravity at the moment of foot contact with the ground.

There is an interdependent relationship among these parameters. It has been suggested that each is controlled by the central movement regulation processes and influenced by the biomotor and morphological characteristics of each athlete (Mero, Komi, & Gregor 1992; Locatelli & Arsac, 1995).

Luhtanen and Komi (1980) divided the contact phase of the sprint step in block acceleration into a braking phase and a propulsion phase. The sum of both of these parts together constitutes the total contact time. Owing to the changing biomechanical conditions of the athlete that take place during the sprint, the contact phase/flight phase also changes. Total ground contact times decrease and flight phases increase. The length of the step depends primarily on body height and/or leg length and the force developed by the extensor muscles of the hip (m. gluteus maximus), knee (m. vastus lateralis, m. rectus femoris) and ankle joint (m. gastrocnemius) in the contact phase and also to the athlete’s basic motor control and coordination.

Execution of the contact phase is one of the most important generators of sprint velocity efficiency (Čoh *et al.,* 2006). The contact phase has to be as short as possible with an optimal ratio between the braking phase and the propulsion phase. Step frequency depends on the functioning of the central nervous system and is largely genetically predetermined (Mero *et al.*, 1992). A very high the step frequency means a shorter step length, and vice versa. The efficiency of block acceleration is defined by an optimal ratio between the length and frequency of the athlete's steps (Čoh *et al.*, 2006).

In the study conducted by Čoh *et al.* (2006), it was found that there was a strong correlation between the start and block acceleration. An optimally set position guarantees the maximal block velocity of the sprinter. The transition from block velocity to block acceleration depends on the execution of the first step, particularly the length of the step and positioning of the foot in the braking phase. The efficiency of block acceleration generates the time aspect of the contact/flight index in the first ten steps. Step length and frequency have to be coordinated to such an extent as to enable ground contact times to equal those of the flight phases within the shortest time possible. In the first three steps, the total body's centre of gravity has to rise gradually in a vertical direction so as to enable the maximization of the horizontal component of block velocity.

The Sprint Stride

There are two main phases of the running stride: the supporting and the non-supporting phases of each limb. The supporting phase consists of the breaking, amortization and propulsion phases. The non-supporting phase consists of the rising and falling phases.

The supporting phase starts at touchdown. At ground contact the knee is locked in an approximately 170^0 position and the ankle is stabilized by surrounding muscles in 110^0 of plantar-flexion (Chu & Korchemny, 1989). According to Chu & Korchemny (1989) in order to minimize the breaking effect of ground contact the optimum landing distance of the foot in front of the centre of gravity should be less than 40cm. A distance greater than this increases horizontal breaking forces, decreasing stride length and stride rate. Lower-leg rotational speed indicates the amount of breaking that occurs during ground contact. If the lower limb can be moving at a velocity close to zero at ground contact there will be minimal breaking.

Ideal technique would be to complete lower-leg extension in sufficient time during the air phase to be able to produce a significant amount of lower-leg flexion speed at touchdown. This results in a reduction in the forward breaking force during the initial portion of ground contact influencing positively the velocity of running and stride length (Mann & Herman, 1985; Hay, 1978). The body passes over the rigid grounded leg (the amortization phase) until the point where the ground reaction forces add horizontal drive to the forward-moving body (the propulsion phase). Energy stored during the eccentric portion of the amortization phase is now utilized during the following take off phase.

During take off, the grounded leg actively extends both at the hip and the ankle to launch the athlete into the flying trajectory with a small angle (2-3 degrees). This is to minimize the height of the centre of gravity from the running position (too high centre of gravity during the flight phase will lead to excessive breaking forces at ground contact during the next stride). After leaving the ground, the athlete actively prepares for a dynamic landing (Hay, 1978; Mann & Herman, 1985).

The second component of the running stride is the non-supporting phase. The first part of this phase is characterized by the lifting of the centre of gravity to the level of the highest point in the stride trajectory. The second part is characterized by the descent of the centre of gravity and the action of the swing leg through the amortization phase. After take-off, the backward-moving leg reaches its maximal extended position whilst the front leg is brought to its optimal flexed position. The back leg then flexes at the knee and starts moving forward toward the downward moving front leg (Hay, 1978; Mann & Herman, 1985).

Knee flexors should hold the swing leg in a flexed position (30 degrees at the knee) during the entire supporting leg amortization phase, as this will increase the speed with which this limb can be cycled to the front position. Moving forward and downward, the swinging leg's momentum increases force applied over the supporting leg. As it passes the vertical, the swinging leg starts to move forward and upward. Its ballistic momentum assists in the forward acceleration of the moving body's centre of gravity. To control these actions through the propulsion phase, the athlete should bring the foot of the flexed leg through at the same level as the supporting knee, triggering this action with dorsi-flexion of the swing leg ankle. The athlete's centre of gravity should not rise over a vertical displacement of greater than 6cm during each flight phase, as this will increase the supporting phase contact time, which in turn will decrease the distance of the flying trajectory. This will reduce the rate of the leg turnover and ultimately the stride length. Sprint acceleration is determined by the relative duration of the support phase (Mann & Herman, 1985), and too much time spent in the amortization phase will decrease stride rate and stride length resulting in a slower horizontal velocity (Hay, 1978; Mann & Herman, 1985).

The Optimal Sprint

Too long a stride length (over-striding) may decrease stride frequency while too rapid a stride frequency may shorten stride length. Both of these conditions can decrease sprinting performance (Kunz & Kaufmann, 1981). According to Mero, Komi, Rusko and Hirvonen (1987), stride frequency has a more important role in maximal sprinting performance than stride length. Optimal values for stride length and stride frequency exist for each sprinter. The optimal relationship between these factors for an individual sprinter depends on his standing height, leg length, crural index, explosiveness of muscular contractions, and speed of movement of his limbs (Kunz & Kaufmann, 1981).

In studies where the same subjects ran at different speeds, both stride frequency and stride length increased with increasing speed (Hoshikawa, Matsui & Miyashita, 1973). These increases are primarily linear up to 7 m/s whereas at higher speeds there is a smaller increment in stride length and a greater increment in stride rate for a given increase in velocity. Yokoi, Shibukawa and Hashihara (1987) studied two groups of differing stature (average leg length difference of 7cm) and similar running velocities (9.30 m/s longer-legged group to 9.36 m/s for the shorter-legged group). They found that the longer-legged athletes had an average stride length of 2.34m compared to 2.18m for the group with shorter legs and an average stride rate of 4.01 compared to 4.35 strides/sec for the group with shorter legs.

As running speed increases, an athlete spends proportionately more time in leg recovery than in leg support, which might suggest that leg recovery is an important factor in sprint running (Wood, 1987). At maximal running speed an athlete aims to spend as little time on the ground as possible. Mann and Herman (1985) found a significant decrease in support time as sprint performance increased under race conditions. They also found that from the analysis of Olympic medallists in the 200m that the major difference between first and second place finishers was their average stride frequency. This result supported earlier research by Mehrikadze and Tabatschnik (1982) who found that differences in stride frequency was the source of significant differences in the performances of elite sprinters.

Hoffman (1971) stated that stride length and leg length both correlated positively with running velocity. Plamondon and Roy (1984) explored relationships between stride frequency, stride length and maximal running velocity. They suggested that there are two specific factors that account for 90% of the variance in running velocity. The first factor was related to the breaking phase component of the support phase (distance the foot is placed forward of the centre of gravity and foot velocity at ground contact). The second factor was the duration of the support phase. Sprint acceleration was especially sensitive to the relative duration of the support phase (Faccioni, n.d.). Mann and Herman (1985) found a significant decrease in support time as sprinting performance improved.

In terms of kinematic variables, Mann and Herman (1985) stated that the greatest factor dictating success in sprinting is the maximum horizontal velocity that an individual is able to achieve. However, Moravec, Ruzicka, Susanka, Dostal, Kodejs and Nosek (1988) contended that a high maximum running velocity is a condition but not a guarantee of excellent sprint performances. In their study, several athletes reached a maximum running velocity of greater than 11.0 m/s but were not able to better 10.50 seconds over a 100m distance.

Conclusion

When looking at research focused on the physical activity and individuals with intellectual impairments, it does appear that they perform consistently lower than their non-intellectually impaired peers (see Table 4). Not all research has shown this trend, however. The physical fitness status of athletes with intellectual impairments was to be generally better than that of a mixed group of individuals without impairments (Lefevre *et al.*, 2000). Elite level INAS-FID athletes scored better on flexibility and running speed than non-intellectually impaired at a lower level of expertise (Van de Vliet *et al.*, 2006).

Because the sprint is a closed skill with a low demand for information processing, it may be a good place to look very closely for movement performance differences between top level athletes with intellectual impairments and matched sprinters who do not have intellectual impairments. The following chapter will outline the methodology followed in order to make a comparison between these two groups.

Table 4.

A summary of the differences found for individuals with intellectual impairments

Physical Fitness Differences	Perceptual-motor Differences
Lower cardiorespiratory endurance and peak heart rates (Fernhall & Pitetti, 2001).	Lower levels of motor proficiency for individuals with intellectual impairments (Dobbins & Rarick, 1977; Londeree & Johnson, 1974).
Elbow and knee extension and flexion less (Horvat *et al.*,1997).	Less balance control (Rider & Abdulahad, 1991).
Lower strength and muscle endurance (Van de Vliet *et al.*, 2006).	Slower speed of limb movement (Lefevre *et al.*, 2000).
Higher average body fat percentage (Lohman *et al.,* 1997).	
Less explosive strength and handgrip strength (Lefevre *et al.*, 2000).	

Chapter Three

Methodology

This study followed a descriptive method in which the movement of intellectually impaired (II) athletes was compared to that of non-intellectually impaired (non-II) athletes, during the first 30m of the acceleration phase of a race.

Procedures

The following procedures were followed in this study.

Selection of the Athletes with Intellectual Impairments

A sample of convenience was used in this study in the selection of the II athletes. The investigator was invited in 2006 to the World Athletics Indoor Championships for Athletes with Intellectual Impairments in Bollnäs, Sweden. The purpose of the invitation was to join an international research project to videotape and analyse the performance of the competitors. All athletes attending the World Indoor Games gave written consent for their filming and analysis prior to the start of the Games. The 32 II athletes (22 male and 10 females) who competed in the 60m sprint event became the II subjects in this study. The rationale for including both males and females in the same group is based on the purpose of this study, which is to address the challenge to develop a classification system for athletes with intellectual impairments. Such a system would not be gender-specific so it was reasoned that this study should examine sprinting from a kinematic perspective only, and not a gender perspective.

Selection of Athletes without Intellectual Impairments

Appropriate non-II athletes had to be identified to use as a comparison group. The sprinting performances of non-II athletes movement was taken to be the ‘norm’ for this investigation. The investigator invited the best sprinters from the Stellenbosch Athletics Club to volunteer to have their sprinting performance videotaped on the athletics track. All 14 athletes (10 males and 4 females) who volunteered to participate provided written consent before the recording session began.

Recording of Sprint Performances

The video recording of sprint performances took place in two different countries and on two different athletic tacks. While the recordings were made at different tracks, the similarities that exist between the two tracks made it possible for the recording and analysis to be done from approximately the same points and on both tracks. This allowed for acceptable consistency in the circumstances surrounding the recording and analysis phase. Time was taken from the gun that could be seen and started from a visual flash seen on the camera and not by sound to measure as accurate time as possible.

Recording the Athletes with Intellectual Impairments

The investigator in cooperation with three other sport scientists did all of the filming of the sprinters after receiving an intensive training session from the research team leader. All of the athletes were recorded on an indoor athletics track on three AOS 100Hz high-speed digital video cameras (see Figure 3).

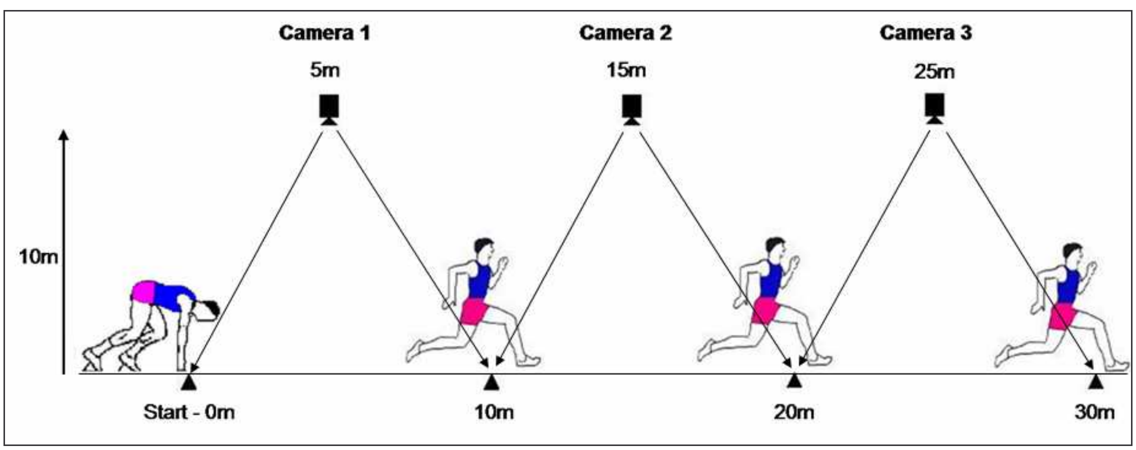

Figure 3

Graphical representation of camera setup for the sprint of the intellectually impaired athletes

Camera One was positioned on the 5m mark, 10m back from the athlete's performance. This camera recorded the athlete's performance from the start to the 10m mark.

Camera Two was positioned was positioned on the 15m mark, 10m back from the athletes performance. This camera recorded the athlete's performance from the 10m mark to the 20m mark.

Camera Three was positioned was positioned was positioned on the 15m mark, 10m back from the athletes performance. This camera recorded the athlete's performance from the 10m mark to the 20m mark.

The following is the sequence of steps followed during the recording session.

1. Marking the track at the starting point with cones, the10m, the 20m point, and the 30m point, and the finish at the 60m point (all with cones).

2. Setting up clear calibration scales for each camera. This is done by placing a one meter reference frame in each of the camera views.

3. Setting up video cameras and tripods at the suitable positions and distances for optimal recording of athletes.

4. Insertion of new clear DV (digital video) videotapes into all of the cameras and test video cameras.

5. When the athletes have finished warming up and indicate they are ready, individually record the athletes as they run, one at a time.

6. Pause filming between each athlete to prolong the filming time on DV digital standard tapes.

7. Stop filming when all athletes have completed their individual runs.

8. Collect all marking apparatus on track, and remove any markings done on the track.

9. Pack away all cameras and tripods.

Recording the Athletes without Intellectual Impairments

The investigator in cooperation with one other sport scientist and with the aid of two sport science students did all of the filming of the sprinters after receiving an intensive training session from the research team leader. All of the athletes were recorded on an outdoor athletics track on three Panasonic 50Hz digital video cameras.

The same camera setup and the sequence of steps followed during the recording session were followed in the recording of the non-intellectually impaired athletes as in the intellectually impaired athletes. Refer to Figure 3 (above).

Analysis of Sprint Performances

Hay (1978) provided the classic framework identifying the relationship among the critical components involved in sprinting performance (see Figure 4). According to Hamill and Knutzen (2003) the following definitions of the critical kinematic variables involved in sprinting can be used:

- **Time** is defined as the period an object takes to do any particular task. The unit of time is seconds (s).
- **Distance** is defined as the total journey an object takes in its travel. Distance may or may not be a straight line from the starting point to the end point (m).
- **Displacement** is defined both by how far the object has moved from its starting position and by the direction it moved. Displacement is measured in a straight line from one position to the next (m).
- **Stride length** is defined as the distance covered by one stride (m).
- **Stride frequency** is defined as the number of strides per minute (Strides/min).

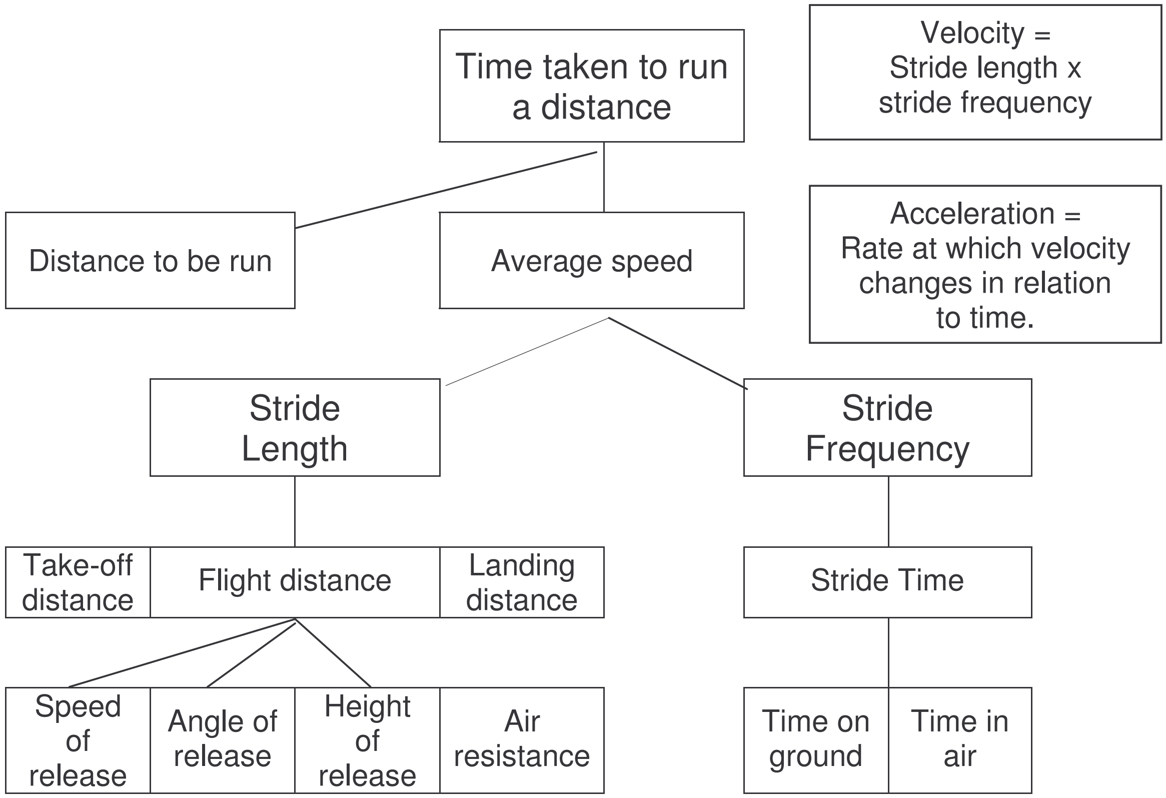

Figure 4

An adaptation of Hay's (1978) framework of the components that affect sprinting performance

- **Velocity** is a vector quantity defined as the rate of change of position. The unit of velocity is meters per second (m/s).

$$Velocity\ (v) = \frac{displacement\ (\Delta s)}{time\ (\Delta t)}$$

Running velocity is also expressed as the result of the relationship between stride rate and stride length.

$$Running\ Speed = Stride\ Length * Stride\ Frequency$$

- **Speed** is a scalar quantity defined as the distance travelled divided by the time it took to travel (m/s).

$$Speed = \frac{distance}{time}$$

- **Acceleration** is defined as the rate of change of velocity with respect to time. The units of acceleration are the unit of velocity (m/s) divided by the unit of time (m/s^2).

$$Acceleration\ (a) = \frac{velocity\ (m/s)}{time\ (s)}$$

Downloading of Video

The recorded videos of the athletes were downloaded to a computer on which the DartFish ProSuite software programme (version 4.0.9.0) had been installed. This software is aimed at elite athlete performance analysis and allows for the biomechanical and movement analysis of the various videos by a skilled coach or sport technologist.

Analysis of Video

The downloaded video were then analysed using the DartFish ProSuite software programme. The programme allowed the investigator to define key moments of the movement patterns for example mark the front of the foot at first contact with the track. This was done in a frame by frame manner so as to give the most accurate results possible. The time from the gun was also defined so that time and distance could be recorded and analysed.

Validity and Reliability of the Kinematic Analysis Process

Validity refers to the degree to which an assessment instrument or process accurately measures what it claims to measure (Thomas & Nelson, 2001). For this study, the establishment of logical (face) validity was selected as the appropriate method. In this method, experts make their own analysis of performance of a subject, and then their expert opinion is compared with the analysis of the same subject produced by the investigator.

Reliability is concerned with the accuracy of the assessment process in terms of its consistency or repeatability (Thomas & Nelson, 2001). For this study, reliability was defined as the consistency with which the investigator analysed the performances of the athletes. It was determined by the repeatability of the analysis, determined through the re-analysis of the recordings of five athletes each from both the intellectually and non-intellectually impaired groups.

Establishing Validity

For the purpose of this study, the investigator set a goal of achieving a minimum agreement rate of 80% with the experts, as the level for acceptability of the validity of the kinematic analysis process. Video from five II subjects and five non-II subjects were randomly selected to allow the validity to be determined.

Invitation of Experts

Two experts accepted the invitation to participate in the validation process. One was a national South African athletics coach who has successfully prepared international level sprinters. The other was an experienced coach of several sprinters with disabilities, all of whom have earned medals in several international competitions, including the Paralympics. Both experts had used video recordings in the past to assist in the analysis of the performances of their own sprinters.

The Validation Sessions

The validation sessions took place over a period of one day. Each session was approximately one hour long, in order to reduce any possible effects of fatigue. The following steps were followed during the first session:

1. Orientation to the DartFish ProSuite software and its application to kinematic analysis.

2. Trial practice.

   After acquaintance with the software, the expert was given one athlete to get acquainted with the system of athlete analysis.

3. Physical analysis of the selected athletes.

   The expert was allowed to analyse the selected video fully making their own decisions concerning each video and each component being studied in that video at that stage.

Results of the Validity Sessions

The investigator then made a comparison between the experts' analysis of each subject and their analysis of the same subject. This comparison was repeated for each of the 20 selected subjects and rate of agreement with the experts for each of the kinematic variable was calculated (see Table 5). The goal was to achieve a minimum agreement rate of 80% between the experts and the investigator. This goal was achieved, therefore the validity of the analysis process was considered to be acceptable.

Table 5

Validity of the analysis process

Variable Observed	Agreement with analysis of II athletes	Agreement with analysis of non-II athletes	Average rate of agreement with analysis
Total time	95.2%	93.1%	94.2%
Total distance	92.3%	91.1%	91.7%
Time per stride	95.1%	92.7%	93.9%
Step length	91.7%	90.9%	91.3%
Total velocity	91.1%	88.8%	90.0%
Total acceleration	89.4%	84.9%	87.1%
Step velocity	90.3%	86.4%	88.4%
Step acceleration	85.2%	82.6%	83.9%
Step Frequency	100.0%	100.0%	100.0%
Total Agreement	92.2%	90.1%	91.2%

Establishing Reliability

The validation sessions took place over a period of two days. Each session was approximately one hour long for the reasons previously described.

Reliability in the athlete analysis process is critical. If a measurement instrument cannot yield the same results upon successive trials then the test cannot be trusted (Thomas & Nelson, 2001).

The Reliability Session

Two sessions were scheduled for the re-analysis of five athletes, from each intellectually and non-intellectually athlete groups. These athletes were randomly selected from each of the groups. For each session, the following steps were followed:

1. A DV tape with the appropriate video clips was selected and then re-loaded on the DartFish ProSuite software programme so that it was ready to be re-analyzed.

2. The clip was then re-analyzed by the investigator following the same steps as previously followed during the initial analysis.

3. The results of this new analysis were then recorded for later comparison to the original results.

Results of the Reliability Sessions

After completing the re-analysis of the five athletes, from each intellectually and non-intellectually athlete groups, a comparison was made between the first and the second analysis. The purpose of this comparison was to identify differences between the first and second analysis. The goal was to achieve a minimum agreement rate of 80% between the first and second analysis. This goal was achieved, therefore the reliability of the analysis process was considered to be acceptable. A summary of the results of these comparisons is presented in Table 6.

Table 6

Reliability of the analysis process

Variable Observed	Agreement with 1st analysis of II athletes	Agreement with 1st analysis of non-II athletes	Average rate of agreement with 1st analysis
Total time	96.4%	96.9%	96.8%
Total distance	90.9%	91.6%	91.3%
Time per stride	95.8%	96.6%	96.2%
Step length	90.9%	90.9%	90.9%
Total velocity	89.8%	91.4%	90.6%
Total acceleration	87.0%	88.6%	87.8%
Step velocity	86.0%	86.6%	86.3%
Step acceleration	82.8%	83.4%	83.1%
Stride frequency	100.0%	100.0%	100.0%
Total Agreement	91.1%	91.8%	91.4%

Analysis of the Data

The acceleration phase was defined by the international project team as the first 10m, the second 10m and the third 10m of a 60 meter sprint. The performance of the non-intellectually impaired athletes was taken as “normal,” which meant that the first 10m was equated with the first seven strides, the second 10m with the next four strides, and the third 10m with the next three strides.

Unpaired independent t-tests were use to determine significant differences between the performances of the non-intellectually impaired and intellectually impaired athletes for the first seven strides, next four strides and then the next three strides:

1. Overall time taken for the strides.
2. Mean stride time.
3. Stride frequency.

4. Overall distance covered with the strides.

5. Mean stride length for the strides.

6. Overall velocity obtained for the strides.

7. Mean velocity obtained for the strides.

8. Overall acceleration obtained for the strides.

9. Mean acceleration obtained for the strides.

Conclusion

The first 30m (the acceleration phase) of sprinting performance of 32 II athletes and 14 non-II athletes was video recorded. Nine kinematic variables were identified as critical indicators of sprinting performance. The video record of the performances of five randomly selected athletes from each group was analysed according to these variables. Following the establishment of acceptable levels of validity and reliability for these selected analyses, a kinematic analysis was completed for all the remaining subjects. A comparison of the results for each sprint variable was then made between the performances of the subjects with intellectual impairments to those without intellectual impairments. An identification of those variables on which the two groups differ significantly and those variables, on which there is no significant difference, is presented in the following chapter.

Chapter Four

Results

The following sections are organized to answer the research questions. Data were collected and analysed based on a total of 14 non-II athletes and 23 II athletes.

Research Question One

1. What are the similarities and differences in the sprinting kinematics between II athletes and non-II athletes for the first seven strides of the acceleration phase of a 60m sprint (from the start to approximately 10m)?

Similarities

Similarities were found in the first seven strides on the following dimensions of sprinting performance:

1. Overall time taken for the first seven strides.

2. Mean stride time for the first seven strides.

3. Stride frequency for the first seven strides.

Overall Time Taken for the First Seven Strides

The results of an unpaired t-test analysis comparing the mean times is presented in Table 7.

Table 7

Differences in overall time taken from the start for the first seven strides

Athletes	df	Mean (s)	SD	t	Sig. (2-tail)
Non-II	13	1.92s	0.18	-0.212	0.833
II	22	1.93s	0.22		

From the data in the table it can be seen that there is no significant difference between non-II and II athletes when it comes to the overall time taken from the start for the first seven strides. Figure 5 presents a visual comparison of the mean overall time per stride for the athletes in the two groups.

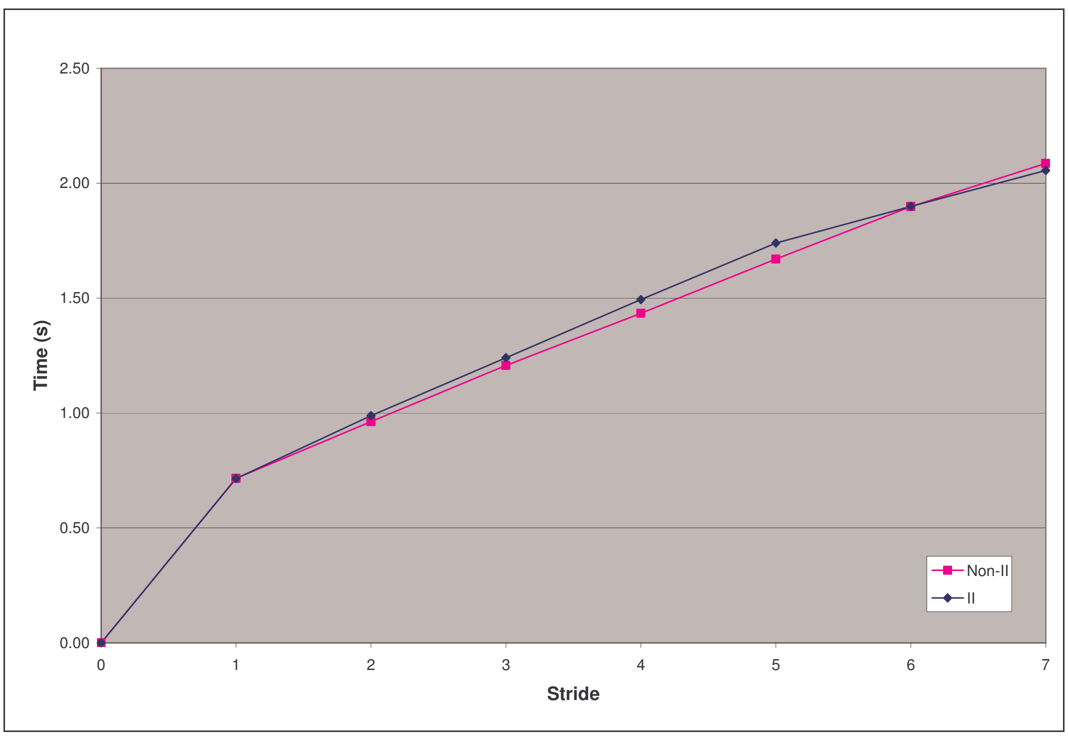

Figure 5

A comparison between non-II and II athletes with regard to the stride number and mean overall time per stride taken from the start for the first seven strides

Mean Stride Time for the First Seven Strides

An unpaired t-test analysis comparing the mean stride times is presented in Table 8.

Table 8

Differences in mean stride time taken from the start for the first seven strides

Athletes	df	Mean (s)	SD	t	Sig. (2-tail)
Non-II	13	0.27	0.21	-0.250	0.804
II	22	0.27	0.33		

From the data in the table it can be seen that there is no significant difference between non-II and II athletes when it comes to the mean stride time taken from the start for the first seven strides. Figure 6 presents a visual comparison of the mean overall time per stride for the athletes in the two groups.

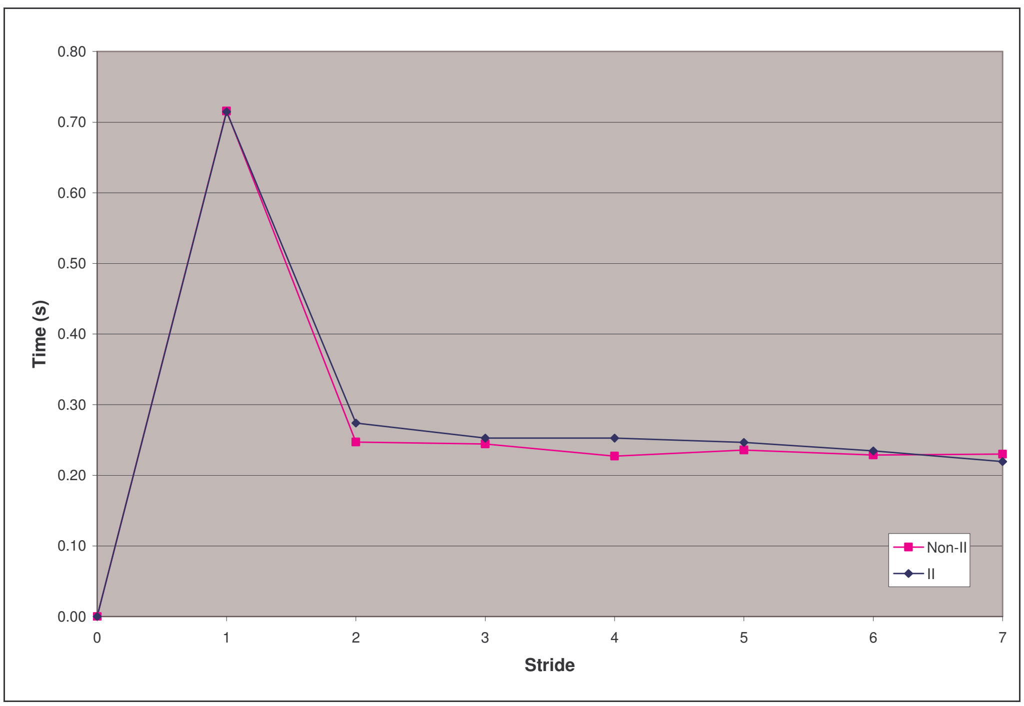

Figure 6

A comparison between non-II and II athletes with regard to the stride number and mean stride time per stride covered from the start for the first seven strides

Stride Frequency for the First Seven Strides

An unpaired t-test analysis comparing the stride frequency is presented in Table 9.

Table 9

Differences in mean stride frequency from the start for the first seven strides

Athletes	df	Mean (strides/min)	SD	t	Sig. (2-tail)
Non-II	13	197.8	16.94	0.728	0.471
II	22	192.1	26.09		

From the data in the table it can be seen that there is no significant difference between non-II and II athletes when it comes to the stride frequency obtained from the start for the first seven strides. Figure 7 presents a visual comparison of the mean overall time per stride for the athletes in the two groups.

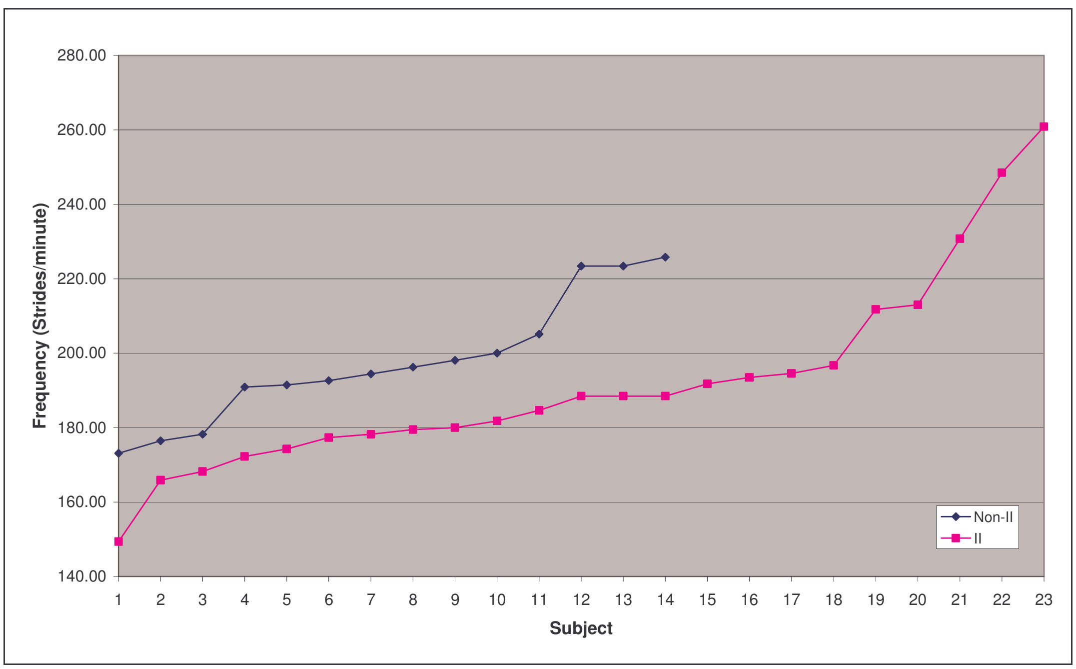

Figure 7

A comparison between non-II and II athletes with regard to the stride frequency (strides/minute) from the start for the first seven strides

Differences

Differences were found in the first seven strides on the following dimensions of sprinting performance**:**

1. Overall distance covered for the first seven strides.
2. Mean stride length for the first seven strides.
3. Overall velocity obtained for the first seven strides.
4. Mean velocity obtained for the first seven strides.
5. Overall acceleration obtained for the first seven strides.
6. Mean acceleration obtained for the first seven strides.

Overall Distance Covered for the First Seven Strides

An unpaired t-test analysis comparing the mean distance is presented in Table 10.

Table 10

Difference in overall distance covered from the start for the first seven strides

Athletes	**df**	**Mean (m)**	**SD**	**t**	**Sig. (2-tail)**
Non-II	13	8.83	0.84	7.823	0.000
II	22	6.93	0.64		

From the data in the table it can be seen that there is a significant difference between non-II and II athletes when it comes to the overall distance covered from the start for the first seven strides. Figure 8 presents a visual comparison of the overall distance per stride for the athletes in the two groups.

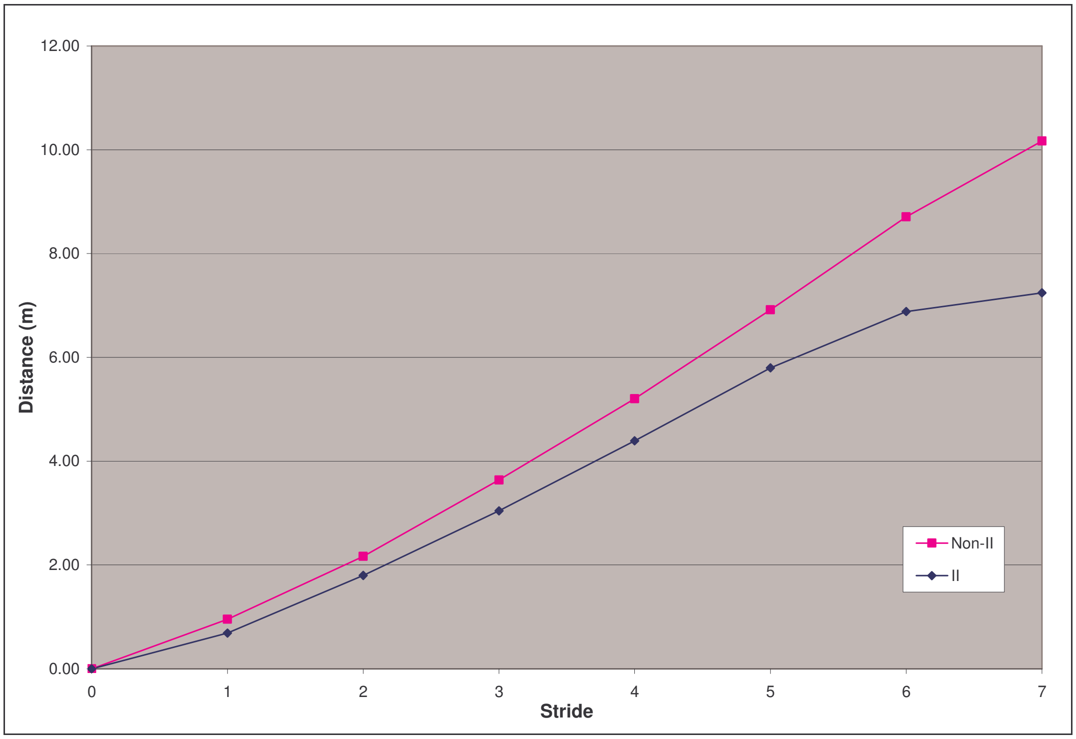

Figure 8

A comparison between non-II and II athletes with regard to the stride number and mean overall distance per stride covered from the start for the first seven strides

Mean Stride Length for the First Seven Strides

An unpaired t-test analysis comparing the mean stride length is presented in Table 11.

Table 11

Difference in mean stride length covered from the start for the first seven strides

Athletes	df	Mean (m)	SD	t	Sig. (2-tail)
Non-II	13	1.25	0.10	8.033	0.000
II	22	0.98	0.10		

From the data in the table it can be seen that there is a significant difference between non-II and II athletes when it comes to the mean stride length covered from the start for the first seven strides. Figure 9 presents a visual comparison of the mean stride length per stride for the athletes in the two groups.

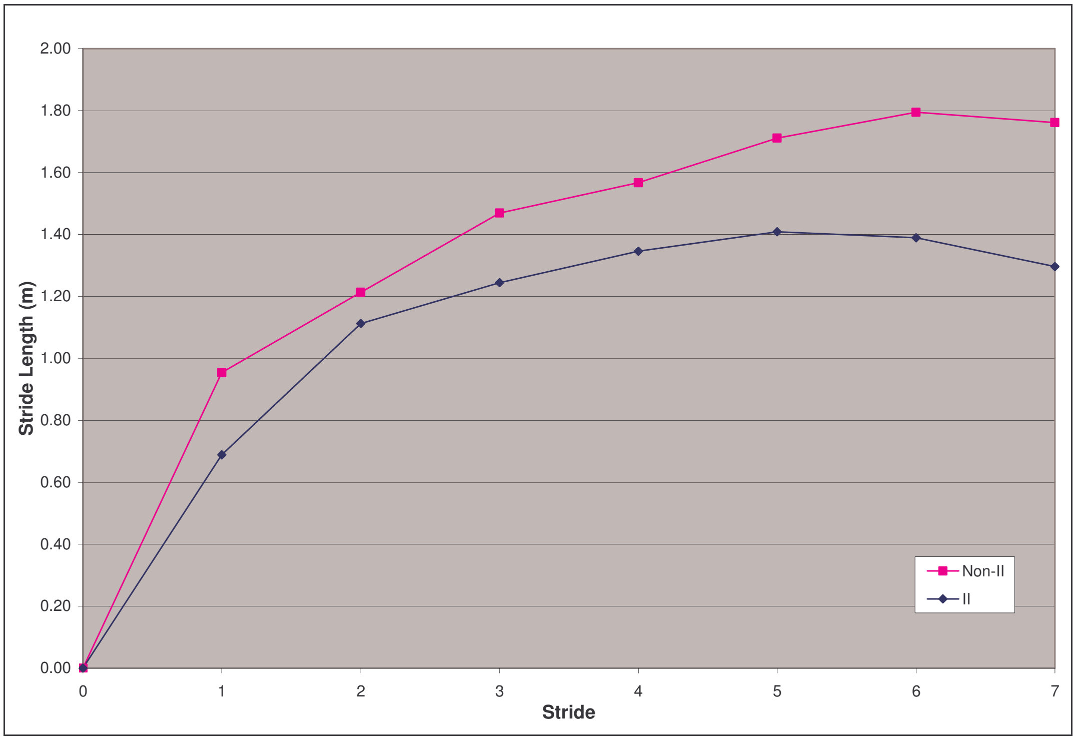

Figure 9

A comparison between non-II and II athletes with regard to the stride number and mean stride length per stride covered from the start for the first seven strides

Overall Velocity for the First Seven Strides

An unpaired t-test analysis comparing the mean velocity is presented in Table 12.

Table 12

Difference in overall velocity from the start for the first seven strides

	df	Mean ($m.s^{-1}$)	SD	t	Sig. (2-tail)
Non-II	13	4.62	0.31	7.131	0.000
II	22	3.63	0.46		

From the data in the table it can be seen that there is a significant difference between non-II and II athletes when it comes to the overall velocity obtained from the start for the first seven strides. Figure 10 presents a visual comparison of the mean overall velocity per stride for the athletes in the two groups.

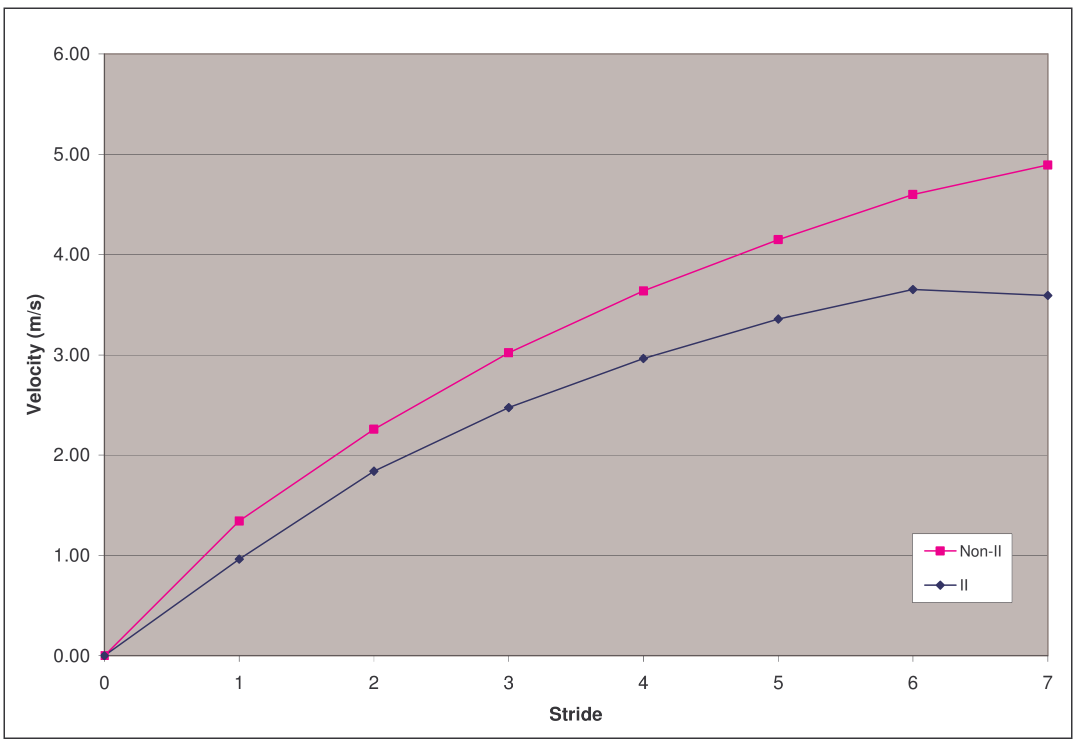

Figure 10

A comparison between non-II and II athletes with regard to the stride number and mean overall velocity per stride covered from the start for the first seven strides

Mean Velocity for the First Seven Strides

An unpaired t-test analysis comparing the mean stride velocity is presented in Table 13.

Table 13

Difference in mean stride velocity from the start for the first seven strides

Athletes	df	Mean ($m.s^{-1}$)	SD	t	Sig. (2-tail)
Non-II	13	4.93	0.27	8.882	0.000
II	22	3.82	0.42		

From the data in the table it can be seen that there is a significant difference between non-II and II athletes when it comes to the mean stride velocity obtained from the start for the first seven strides. Figure 11 presents a visual comparison of the mean stride velocity per stride.

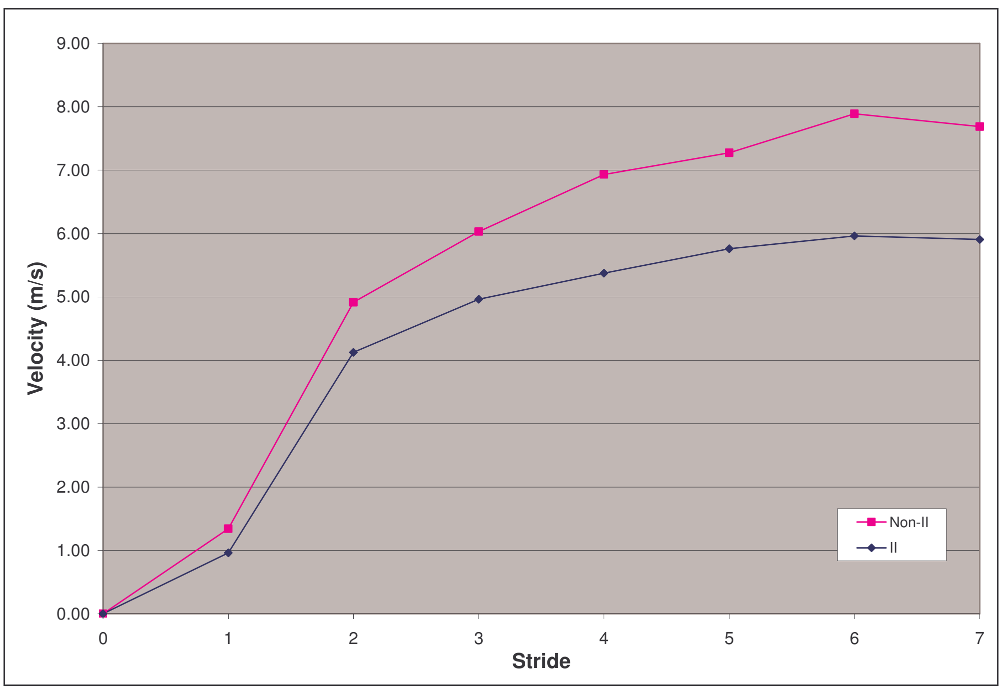

Figure 11

A comparison between non-II and II athletes with regard to the stride number and mean stride velocity per stride covered from the start for the first seven strides

Overall Acceleration for the First Seven Strides

An unpaired t-test analysis comparing the mean acceleration is presented in Table 14.

Table 14

Difference in overall acceleration from the start for the first seven strides

Athletes	df	Mean ($m.s^{-2}$)	SD	t	Sig. (2-tail)
Non-II	13	2.44	0.33	3.795	0.001
II	22	1.92	0.44		

From the data in the table it can be seen that there is a significant difference between non-II and II athletes when it comes to the overall acceleration. Figure 12 presents a visual comparison of the mean overall acceleration per stride for the athletes.

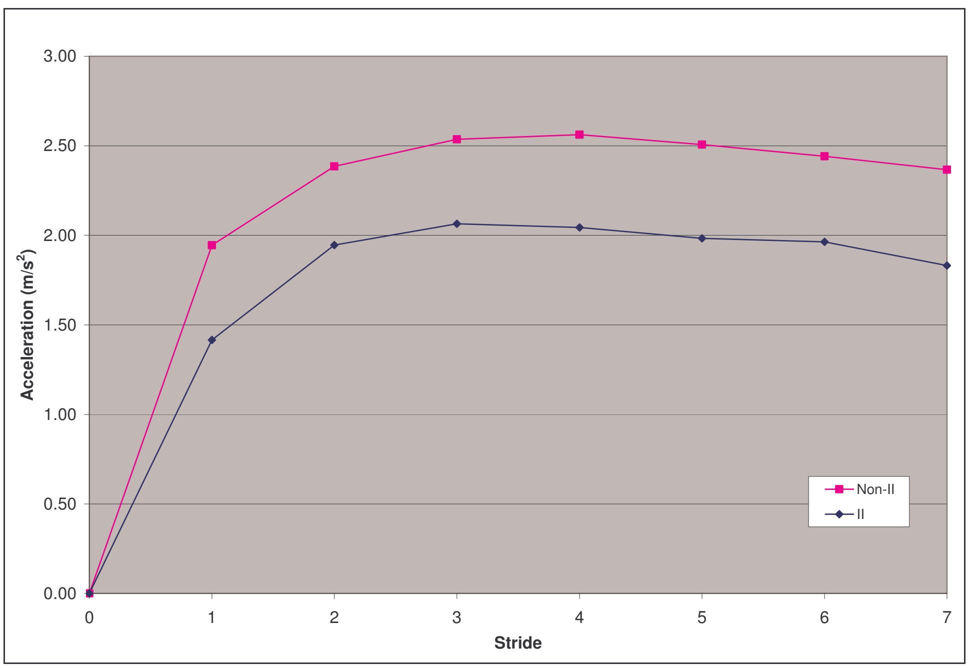

Figure 12

A comparison between non-II and II athletes with regard to the stride number and mean overall acceleration per stride covered from the start for the first seven strides

Mean Acceleration for the First Seven Strides

An unpaired t-test analysis comparing the mean stride acceleration is presented in Table 15.

Table 15

Difference in mean stride acceleration from the start for the first seven strides

Athletes	df	Mean ($m.s^{-2}$)	SD	t	Sig. (2-tail)
Non-II	13	20.63	1.67	6.020	0.000
II	22	15.67	2.79		

From the data in the table it can be seen that there is a significant difference between non-II and II athletes when it comes to mean stride acceleration. Figure 13 presents a visual comparison of the mean per stride for the athletes.

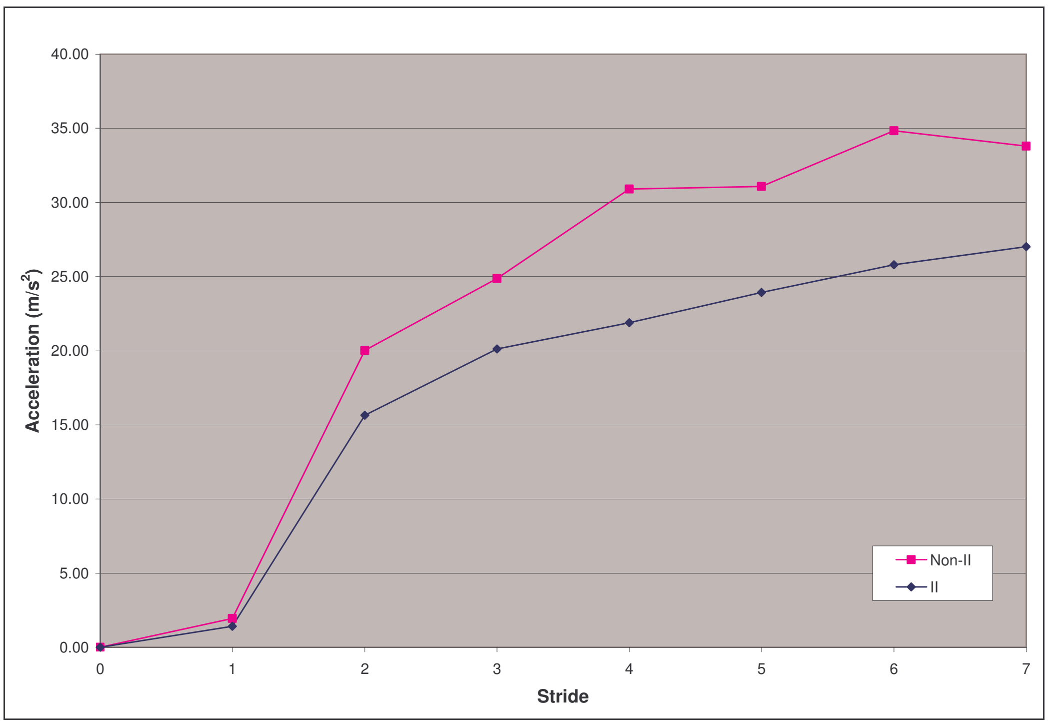

Figure 13

A comparison between non-II and II with regard to the stride number and mean stride acceleration per stride covered from the start for the first seven strides

Research Question Two

2. What are the similarities and differences in the sprinting kinematics between II athletes and non-II athletes from the 10m point for the next four strides of the acceleration phase of a 60m sprint (approximately the second 10m)?

Similarities

Similarities were found from the 10m point for the next four strides on the following dimensions of sprinting performance:

1. Overall time from the 10m point for the next four strides.
2. Mean stride time from the 10m point for the next four strides.
3. Stride frequency from the 10m point for the next four strides.

Overall Time from the 10m point for the Next Four Strides

An unpaired t-test analysis comparing the mean overall time is presented in Table 16.

Table 16

Difference in overall time taken from the 10m point for the next four strides

Athletes	df	Mean (s)	SD	t	Sig. (2-tail)
Non-II	13	0.68	0.2	-0.840	0.406
II	22	0.69	0.7		

From the data in the table it can be seen that there is no significant difference between non-II and II athletes when it comes to the overall time taken from the 10m point for the next four strides. Figure 14 presents a visual comparison of the mean overall time for the athletes in the two groups.

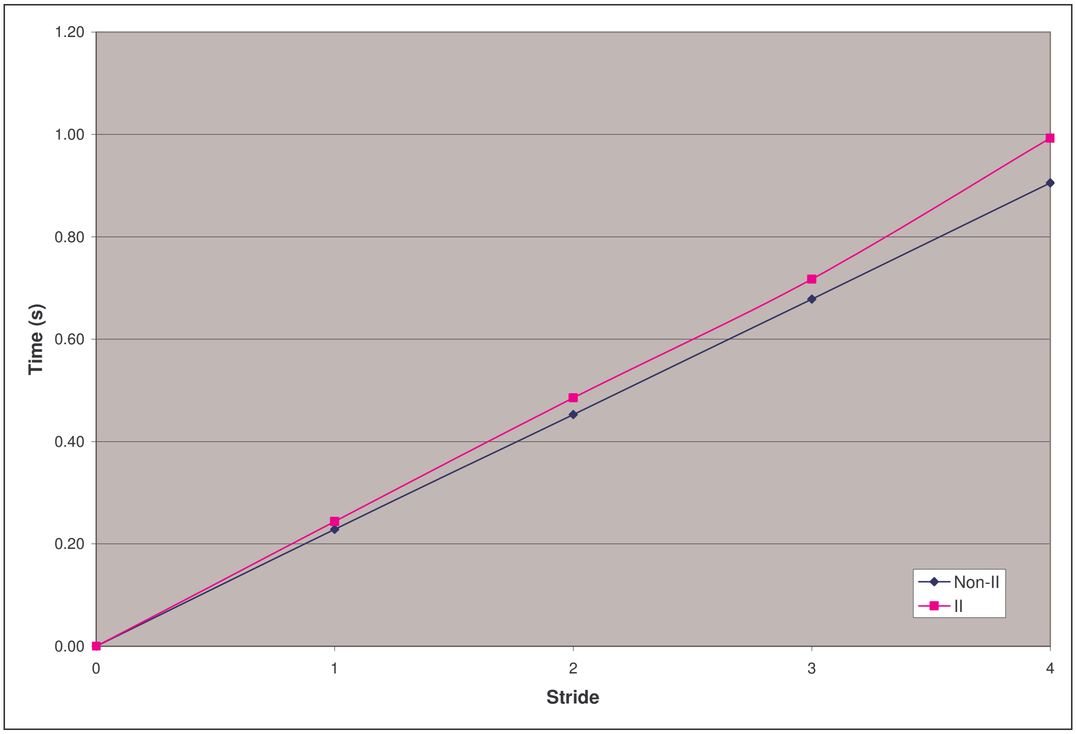

Figure 14

A comparison between non-II and II athletes with regard to the stride number and mean overall time per stride taken from the 10m point for the next four strides

Mean Stride Time from the 10m point for the Next Four Strides

An unpaired t-test analysis comparing the mean stride time is presented in Table 17.

Table 17

Difference in mean stride time taken from the 10m point for the next four strides

Athletes	df	Mean (s)	SD	t	Sig. (2-tail)
Non-II	13	0.17	0.01	0.861	0.395
II	22	0.17	0.02		

From the data in the table it can be seen that there is no significant difference between non-II and II athletes when it comes to the mean stride time taken from the 10m point for the next four strides. Figure 15 presents a visual comparison of the mean stride time for the athletes in the two groups.

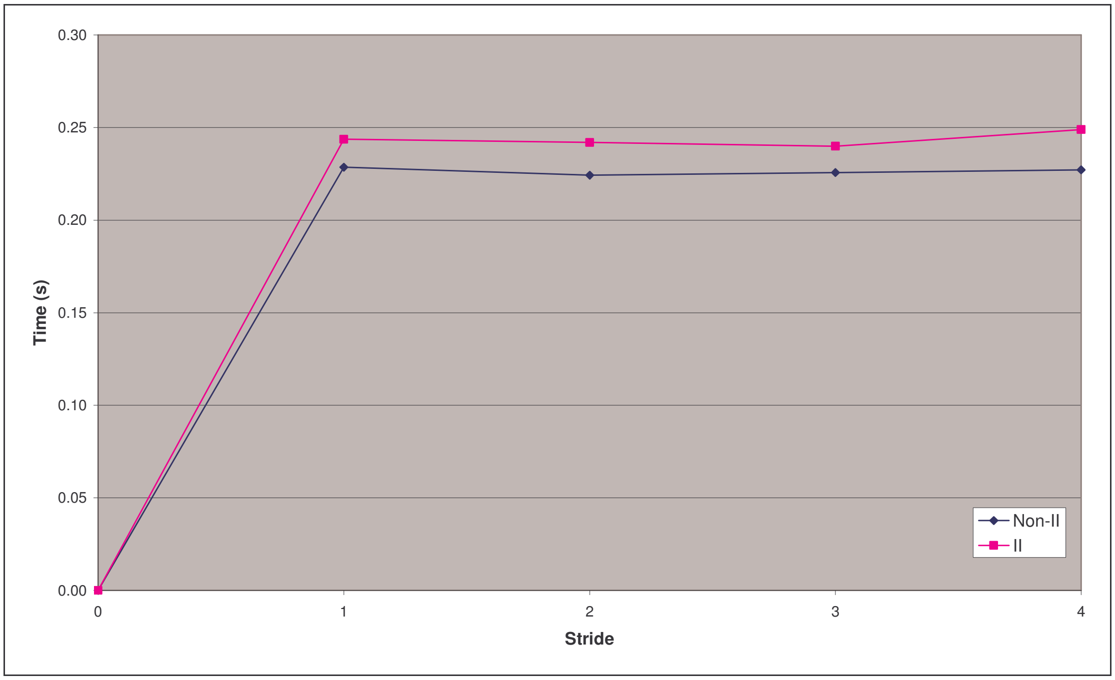

Figure 15

A comparison between non-II and II athletes with regard to the stride number and mean stride time per stride covered from the 10m point for the next four strides

Stride Frequency from the 10m point for the Next Four Strides

An unpaired t-test analysis comparing the stride frequency from the 10m point for the next four strides of the athletes from the two groups is presented in Table 18.

Table 18

Difference in mean stride frequency from the 10m point for the next four strides

Athletes	df	Mean (strides/min)	SD	t	Sig. (2-tail)
Non-II	13	264.7	7.99	0.414	0.681
II	22	261.9	24.42		

From the data in the table it can be seen that there is no significant difference between non-II and II athletes when it comes to the stride frequency obtained from the 10m point for the next four strides. Figure 16 presents a visual comparison of the stride frequency for the athletes in the two groups.

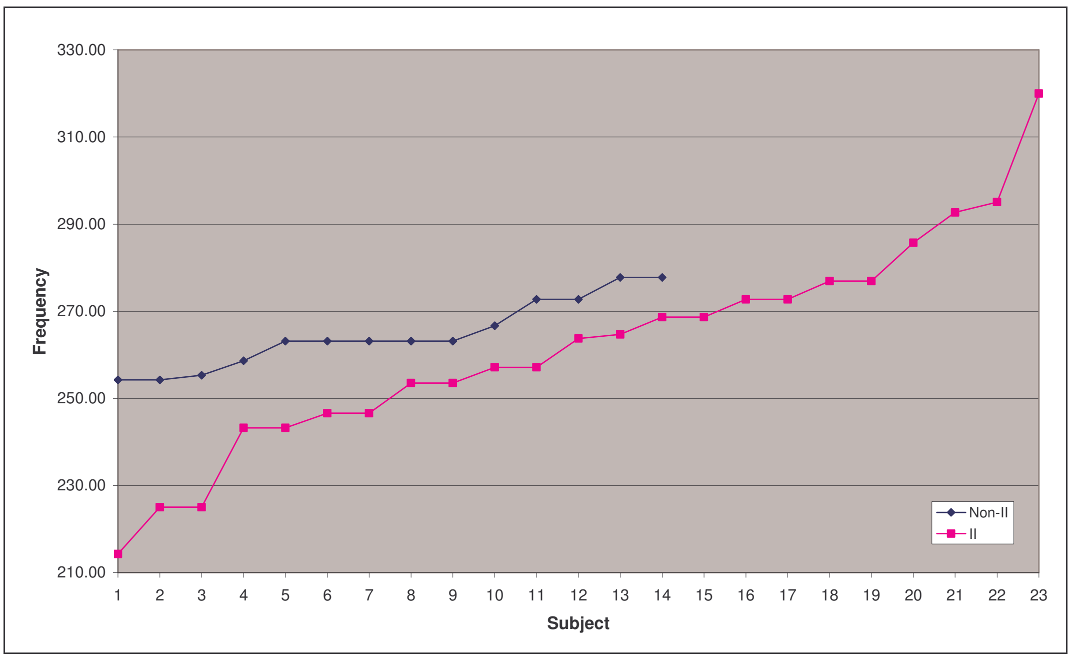

Figure 16

A comparison between non-II and II athletes with regard to the stride frequency from the 10m point for the next four strides

Differences

Differences were found in the first seven strides on the following dimensions of sprinting performance:

1. Overall distance covered from the 10m point for the next four strides.
2. Mean stride length from the 10m point for the next four strides.
3. Overall velocity from the 10m point for the next four strides.
4. Mean velocity from the 10m point for the next four strides.
5. Overall acceleration from the 10m point for the next four strides.
6. Mean acceleration from the 10m point for the next four strides.

Overall Distance Covered from the 10m point for the Next Four Strides

An unpaired t-test analysis comparing the mean overall distance is presented in Table 19.

Table 19

Difference in overall distance covered from the 10m point for the next four strides

Athletes	df	Mean (m)	SD	t	Sig. (2-tail)
Non-II	13	6.02	0.27	9.224	0.000
II	22	5.08	0.32		

From the data in the table it can be seen that there is a significant difference between non-II and II athletes when it comes to the overall distance covered from the 10m point for the next four strides. Figure 17 presents a visual comparison of the mean overall distance for the athletes in the two groups.

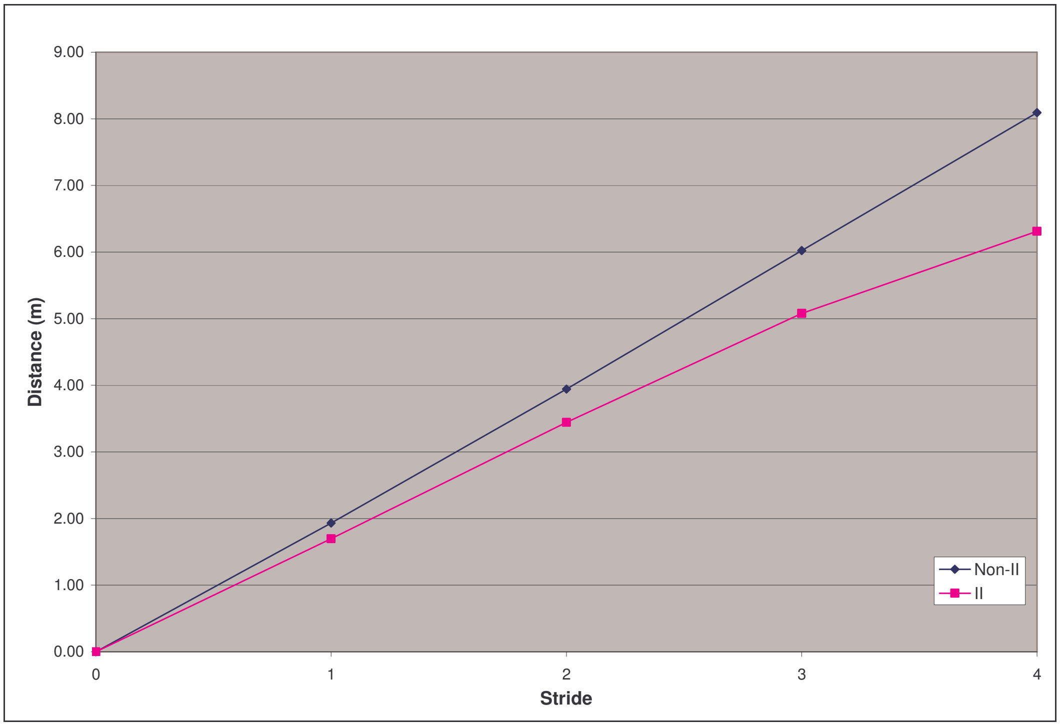

Figure 17

A comparison between non-II and II athletes with regard to the stride number and mean overall distance per stride covered from the 10m point for the next four strides

Mean Stride Length from the 10m point for the Next Four Strides

An unpaired t-test analysis comparing the mean stride length is presented in Table 20.

Table 20

Difference in mean stride length covered from the 10m point for the next four strides

Athletes	df	Mean (m)	SD	t	Sig. (2-tail)
Non-II	13	1.51	0.07	9.282	0.000
II	22	1.27	0.08		

From the data in the table it can be seen that there is a significant difference between non-II and II athletes when it comes to the mean stride length covered from the 10m point for the next four strides. Figure 18 presents a visual comparison of the mean stride length for the athletes in the two groups.

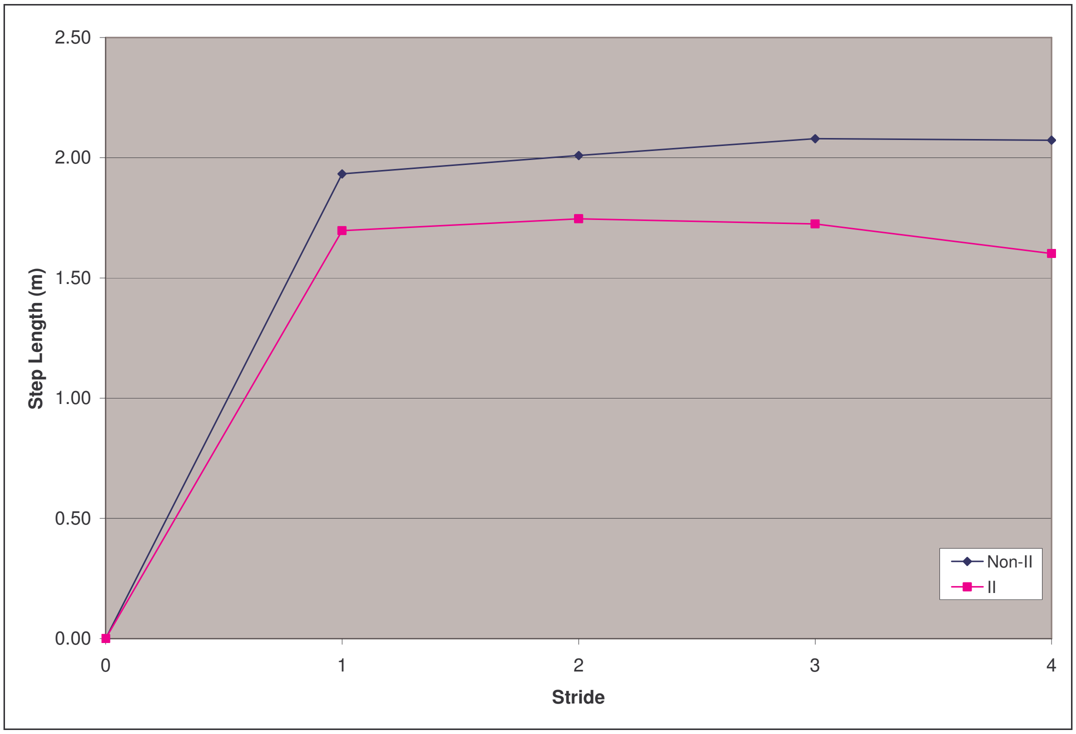

Figure 18

A comparison between non-II and II athletes with regard to the stride number and mean stride length per stride covered from the 10m point for the next four strides

Overall Velocity from the 10m point for the Next Four Strides

Am unpaired t-test analysis comparing the mean overall velocity is presented in Table 21.

Table 21

Difference in overall velocity from the 10m point for the next four strides

Athletes	**df**	**Mean ($m.s^{-1}$)**	**SD**	**t**	**Sig. (2-tail)**
Non-II	13	8.88	0.41	6.472	0.000
II	22	7.38	0.80		

From the data in the table it can be seen that there is a significant difference between non-II and II athletes when it comes to the overall velocity obtained from the 10m point for the next four strides. Figure 19 presents a visual comparison of the mean overall velocity for the athletes in the two groups.

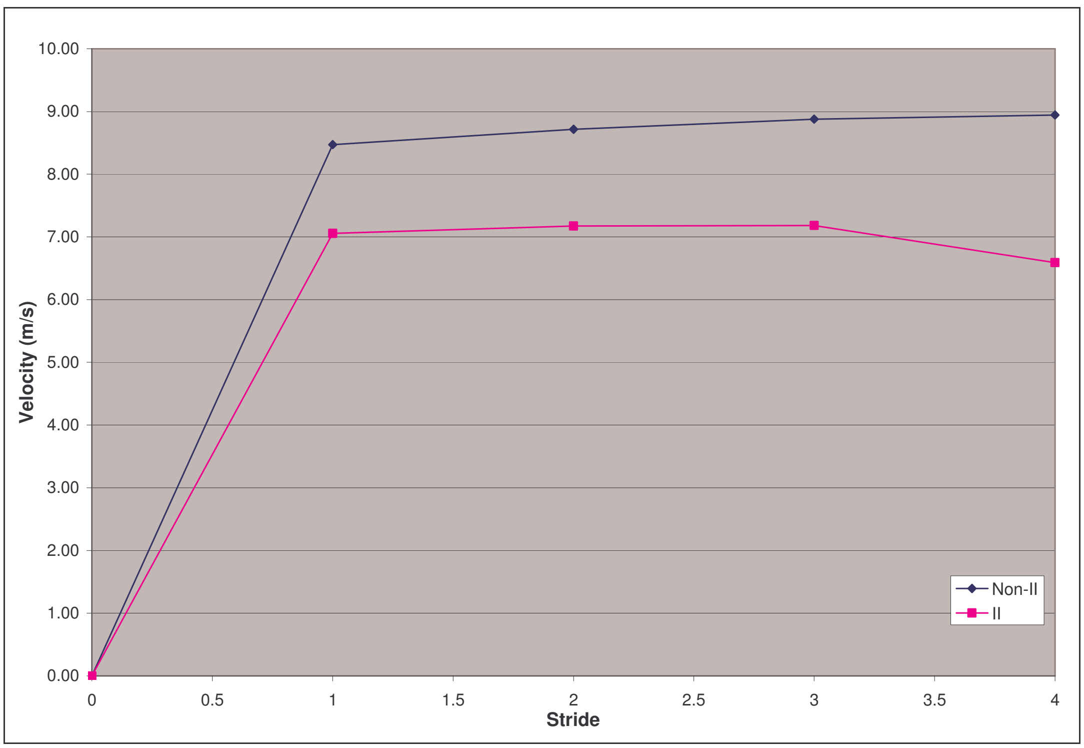

Figure 19

A comparison between non-II and II athletes with regard to the stride number and mean overall velocity per stride covered from the 10m point for the next four strides

Mean Velocity from the 10m point for the Next Four Strides

An unpaired t-test analysis comparing the mean stride velocity is presented in Table 22.

Table 22

Difference in mean stride velocity from the 10m point for the next four strides

Athletes	df	Mean ($m.s^{-1}$)	SD	t	Sig. (2-tail)
Non-II	13	6.65	0.31	6.412	0.000
II	22	5.54	0.60		

From the data in the table it can be seen that there is a significant difference between non-II and II athletes in terms of mean stride velocity from the 10m point for the next four strides. Figure 20 presents a visual comparison of the mean stride velocity for the athletes in the two groups.

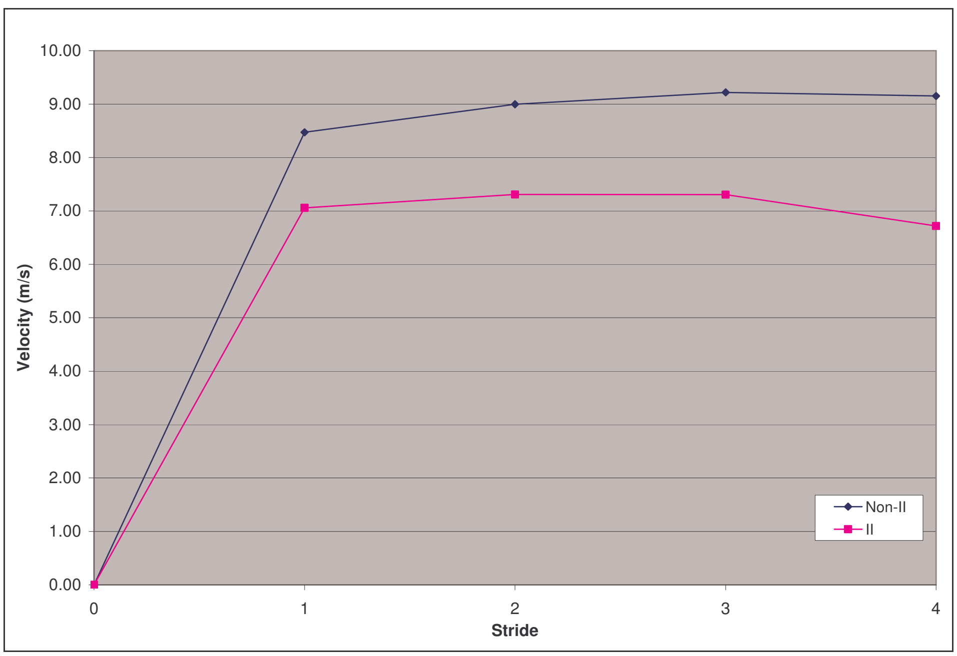

Figure 20

A comparison between non-II and II athletes with regard to the stride number and mean stride velocity per stride covered from the 10m point for the next four strides

Overall Acceleration from the 10m point for the Next Four Strides

An unpaired t-test analysis comparing the mean overall acceleration is presented in Table 23.

Table 23

Difference in acceleration from the 10m point for the next four strides

Athletes	df	Mean ($m.s^{-2}$)	SD	t	Sig. (2-tail)
Non-II	13	13.11	0.92	4.063	0.000
II	22	10.80	2.00		

From the data in the table it can be seen that there is a significant difference between non-II and II athletes when it comes to the overall acceleration obtained from the 10m point for the next four strides. Figure 21 presents a visual comparison of the differences between the two groups.

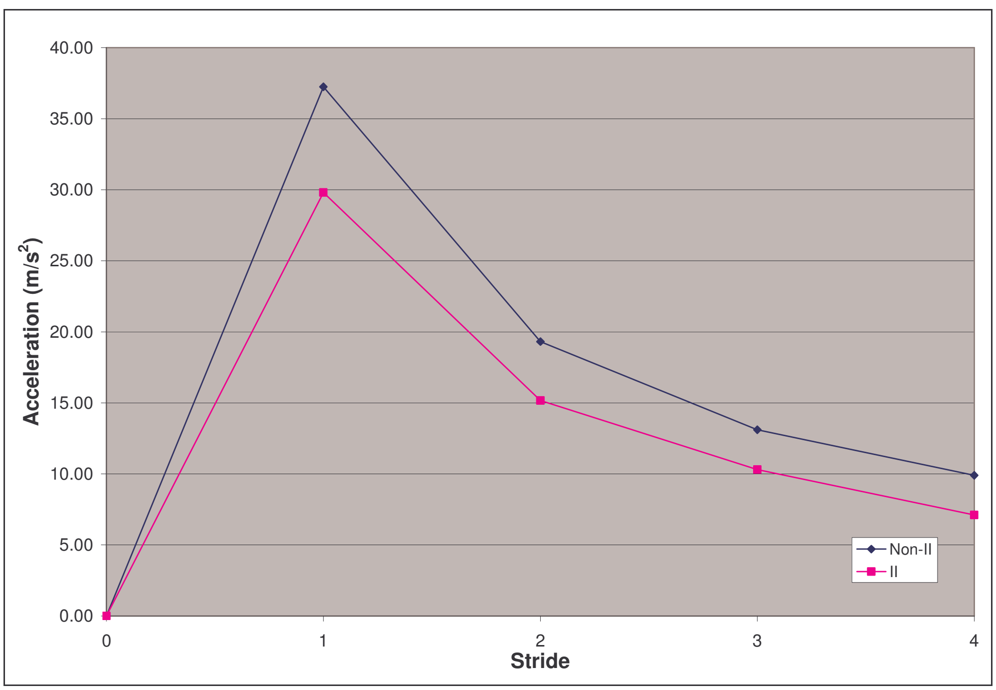

Figure 21

A comparison between non-II and II athletes with regard to the stride number and mean overall acceleration per stride from the 10m point for the next four strides

Mean Stride Acceleration from the 10m point for the Next Four Strides

An unpaired t-test analysis comparing the mean stride acceleration is presented in Table 24.

Table 24

Difference in mean stride acceleration from 10m for the next four strides

Athletes	df	Mean ($m.s^{-2}$)	SD	t	Sig. (2-tail)
Non-II	13	29.36	2.00	3.447	0.001
II	22	23.33	6.32		

Figure 22 presents a visual comparison of the mean overall acceleration for the athletes in the two groups.

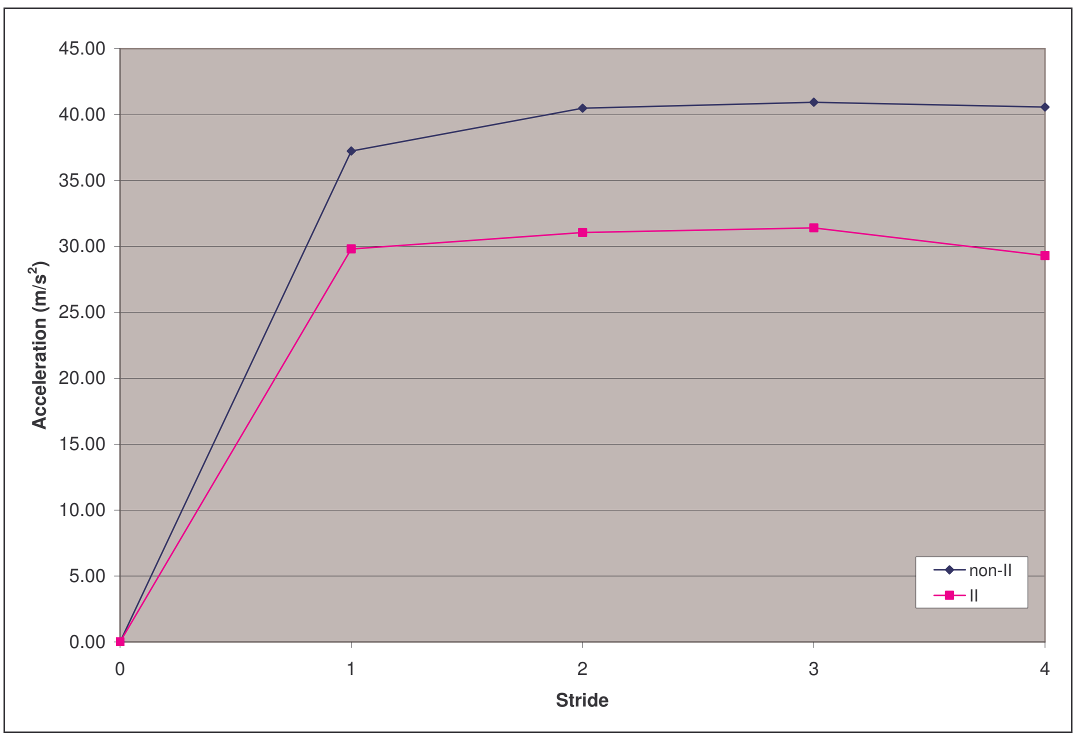

Figure 22

A comparison between non-II and II athletes with regard to the stride number and mean stride acceleration per stride

Research Question Three

3. What are the similarities and differences in the sprinting kinematics of II athletes and non-II athletes from the 20m point for the next three strides (approximately 10m for the non-II athletes)?

Similarities

Similarities were found from the 20m point for the next three strides on the following dimensions of sprinting performance:

1. Overall time taken from the 20m point for the next three strides.

2. Mean stride time from the 20m point for the next three strides.

3. Stride frequency from the 20m point for the next three strides.

Overall Time taken from the 20m point for the Next Three Strides

An unpaired t-test analysis comparing the mean overall time is presented in Table 25.

Table 25

Difference in overall time taken from the 20m point for the next three strides

Athletes	df	Mean (s)	SD	t	Sig. (2-tail)
Non-II	13	0.44	0.18	-2.143	0.039
II	22	0.47	0.47		

From the data in the table it can be seen that there is no significant difference between non-II and II athletes when it comes to the overall time taken from the 20m point for the next three strides. Figure 23 presents a visual comparison of the mean overall time for the athletes in the two groups.

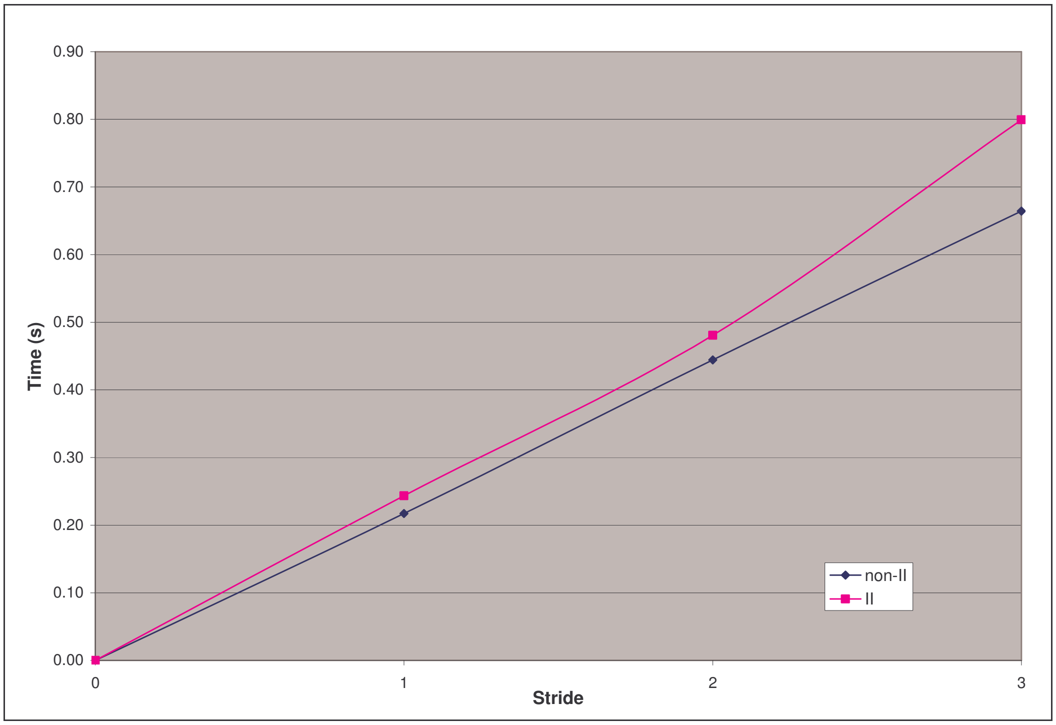

Figure 23

A comparison between non-II and II athletes with regard to the stride number and mean overall time per stride taken from the 20m point for the next three strides

Mean Stride Time from the 20m point for the Next Three Strides

A statistical unpaired t-test analysis comparing the mean stride time is presented in Table 26.

Table 26

Difference in mean stride time taken from the 20m point for the next three strides

Athletes	df	Mean (s)	SD	t	Sig. (2-tail)
Non-II	13	0.15	0.00	-1.595	-0.006
II	22	0.15	0.01		

From the data in the table it can be seen that there is no significant difference between non-II and II athletes when it comes to the mean stride time taken from the 20m point for the next three strides. Figure 24 presents a visual comparison of the mean stride time for the athletes in the two groups.

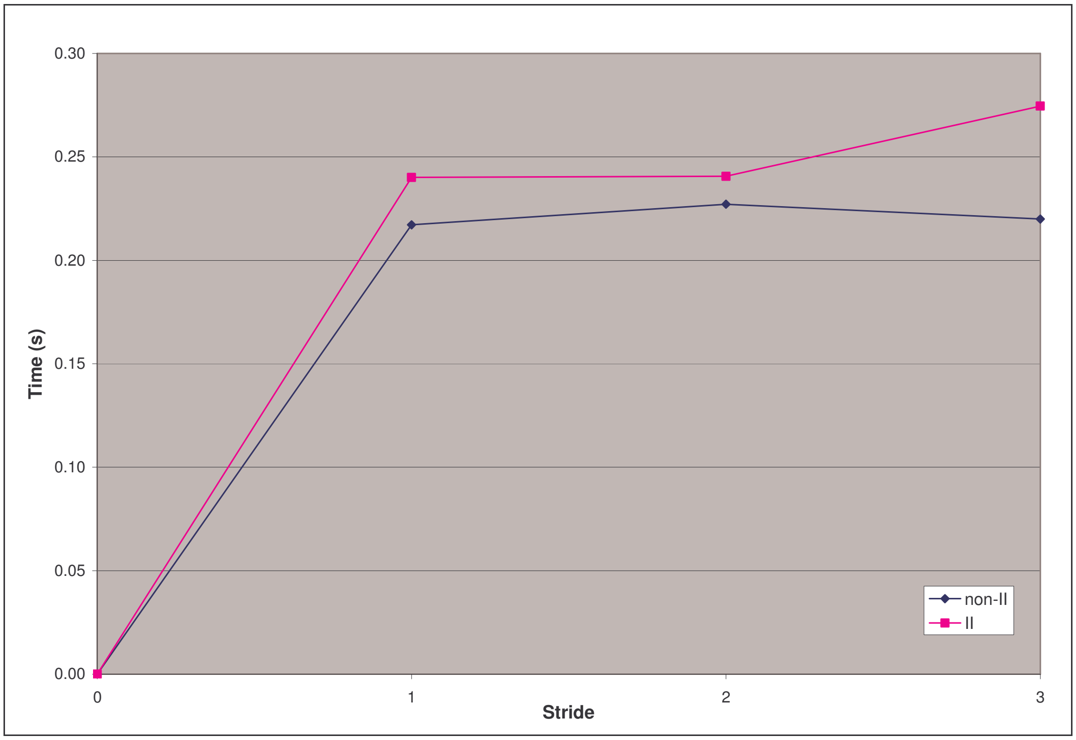

Figure 24

A comparison between non-II and II athletes with regard to the stride number and mean stride time per stride covered from the 20m point for the next three strides

Stride Frequency from the 20m point for the Next Three Strides

An unpaired t-test analysis comparing the stride frequency from the 20m point for the next three strides of the athletes from the two groups is presented in Table 27.

Table 27

Difference in mean stride frequency from the 20m point for the next three strides

Athletes	df	Mean (strides/min)	SD	t	Sig. (2-tail)
Non-II	13	269.8	8.17	1.609	0.117
II	22	256.8	29.27		

From the data in the table it can be seen that there is no significant difference between non-II and II athletes when it comes to the stride frequency obtained from the 20m point for the next three strides. Figure 25 presents a visual comparison of the stride frequency for the athletes in the two groups.

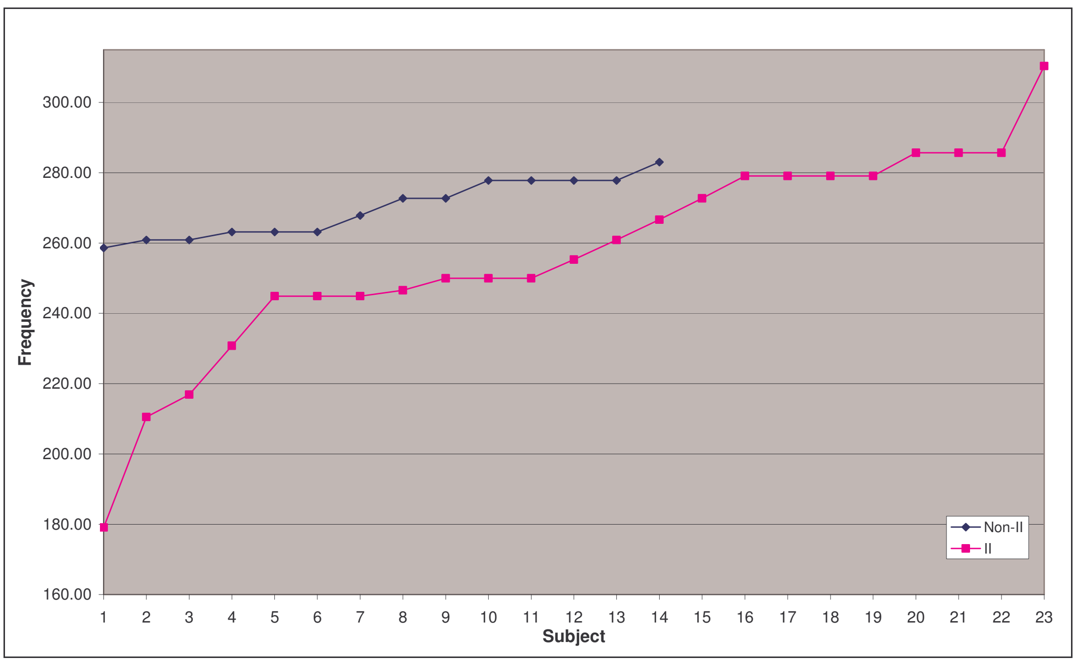

Figure 25

A comparison between non-II and II athletes with regard to the stride frequency from the 20m point for the next three strides

Differences

Differences were found from the 20m point for the next three strides on the following dimensions of sprinting performance:

1. Overall distance covered from the 20m point for the next three strides.
2. Mean stride length from the 20m point for the next three strides.
3. Overall velocity from the 20m point for the next three strides.
4. Mean velocity from the 20m point for the next three strides.
5. Overall acceleration from the 20m point for the next three strides.
6. Mean acceleration from the 20m point for the next three strides.

Overall Distance Covered from the 20m point for the Next Three Strides

An unpaired t-test analysis comparing the mean overall distance is presented in Table 28.

Table 28

Difference in overall distance covered from the 20m point for the next three strides

Athletes	df	Mean (m)	SD	t	Sig. (2-tail)
Non-II	13	4.35	0.16	4.286	0.000
II	22	3.76	0.44		

From the data in the table it can be seen that there is a significant difference between non-II and II athletes when it comes to the overall distance covered from the 20m point for the next three strides. Figure 26 presents a visual comparison of the mean overall distance for the athletes in the two groups.

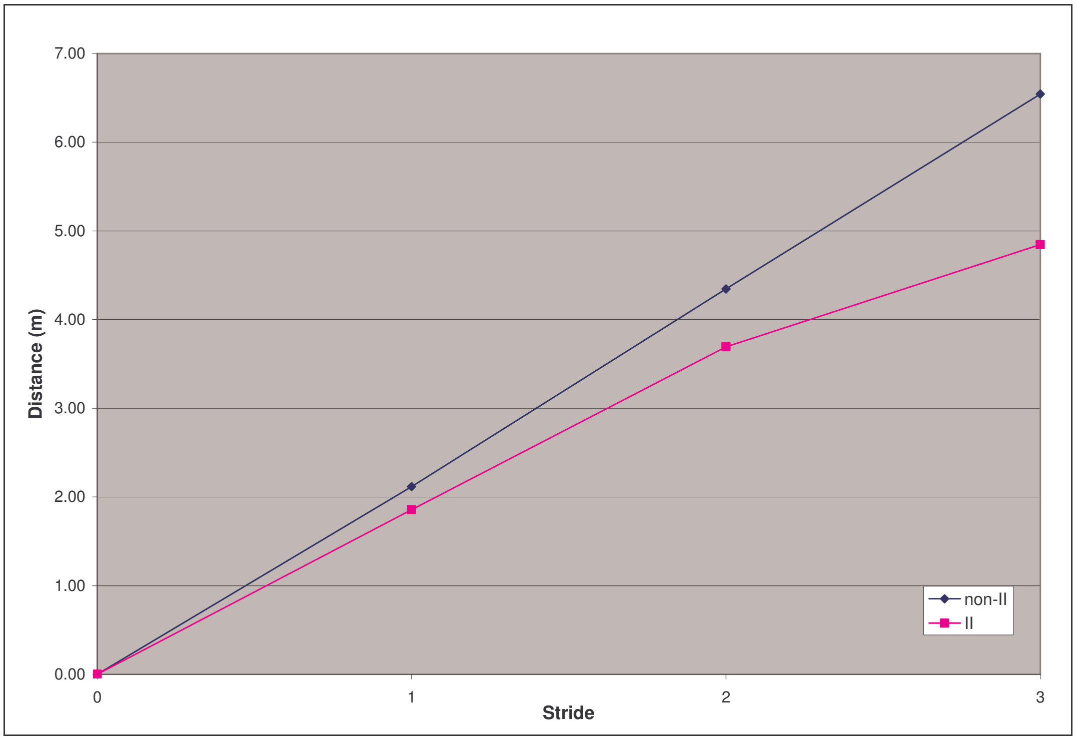

Figure 26

A comparison between non-II and II athletes with regard to the stride number and mean overall distance per stride covered from the 20m point for the next three strides

Mean Stride Length from the 20m point for the Next Three Strides

An unpaired t-test analysis comparing the mean stride length is presented in Table 29.

Table 29

Difference in mean stride length covered from the 20m point for the next three strides

Athletes	df	Mean (m)	SD	t	Sig. (2-tail)
Non-II	13	1.45	0.05	7.206	0.000
II	22	1.23	0.11		

From the data in the table it can be seen that there is a significant difference between non-II and II athletes when it comes to the mean stride length covered from the 20m point for the next three strides. Figure 27 presents a visual comparison of the mean stride length for the athletes in the two groups.

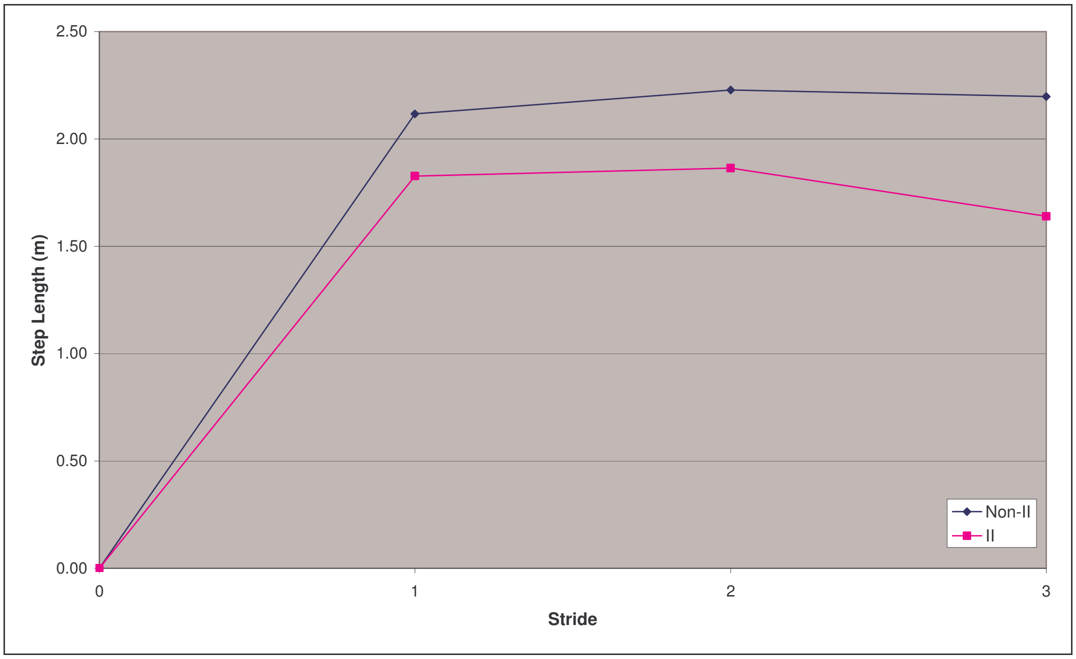

Figure 27

A comparison between non-II and II athletes with regard to the stride number and mean stride length per stride covered from the 20m point for the next three strides

Overall Velocity Obtained from the 20m point for the Next Three Strides

An unpaired t-test analysis comparing the mean overall velocity is presented in Table 30.

Table 30

Difference in overall velocity from the 20m point for the next three strides

Athletes	df	Mean ($m.s^{-1}$)	SD	t	Sig. (2-tail)
Non-II	13	9.80	0.56	5.635	0.000
II	22	8.04	1.08		

From the data in the table it can be seen that there is a significant difference between non-II and II athletes when it comes to the overall velocity obtained from the 20m point for the next three strides. Figure 28 presents a visual comparison of the mean overall velocity for the athletes in the two groups.

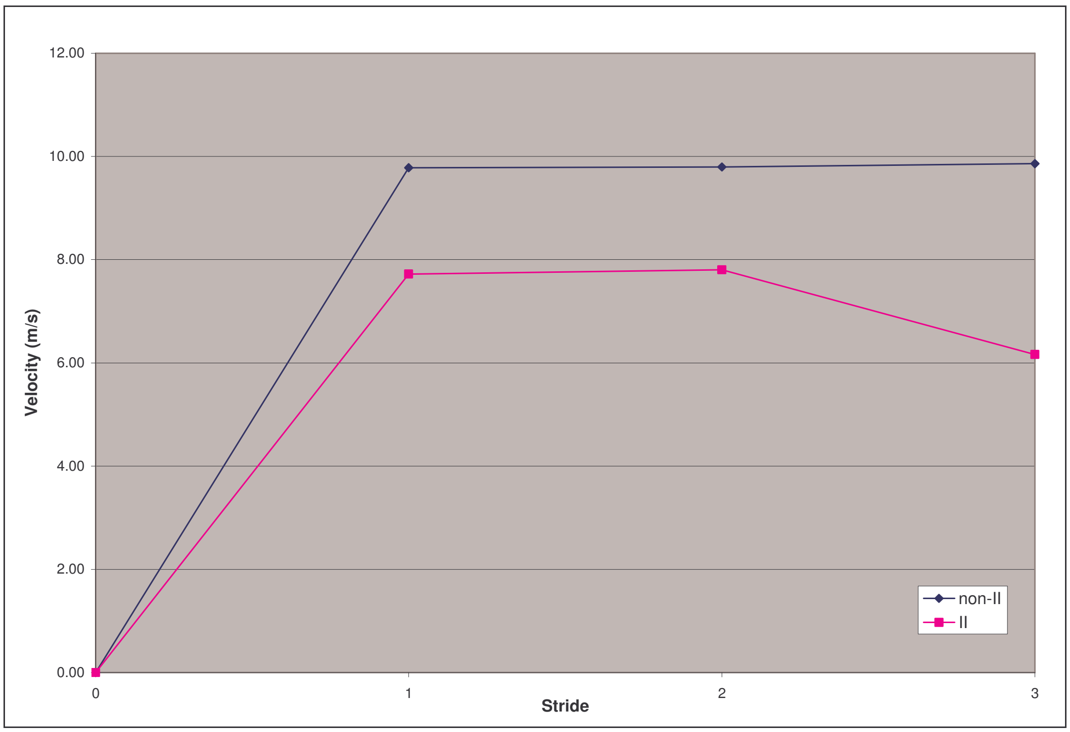

Figure 28

A comparison between non-II and II athletes with regard to the stride number and mean overall velocity per stride covered from the 20m point for the next three strides

Mean Velocity from the 20m point for the Next Three Strides

An unpaired t-test analysis comparing the mean stride velocity is presented in Table 31.

Table 31

Difference in mean stride velocity from the 20m point for the next three strides

Athletes	df	Mean ($m.s^{-1}$)	SD	t	Sig. (2-tail)
Non-II	13	6.54	0.37	5.656	0.000
II	22	5.35	0.72		

There is a significant difference between non-II and II athletes. Figure 29 presents a visual comparison of the mean stride velocity for the athletes.

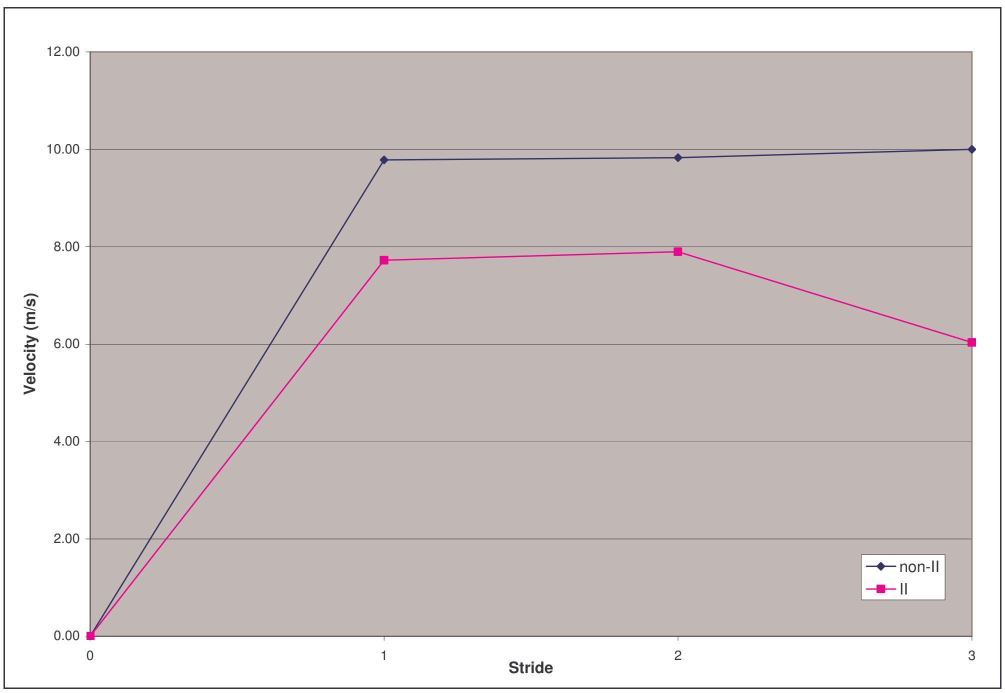

Figure 29

A comparison between non-II and II with regard to the stride number and mean stride velocity per stride covered from the 20m point for the next three strides

Overall Acceleration from the 20m point for the Next Three Strides

An unpaired t-test analysis comparing the mean overall acceleration is presented in Table 32.

Table 32

Difference in overall acceleration from the 20m point for the next three strides

Athletes	df	Mean ($m.s^{-2}$)	SD	t	Sig. (2-tail)
Non-II	13	22.12	2.05	4.717	0.000
II	22	17.29	3.47		

From the data in the table it can be seen that there is a significant difference between non-II and II athletes. Figure 30 presents a visual comparison of the mean overall acceleration.

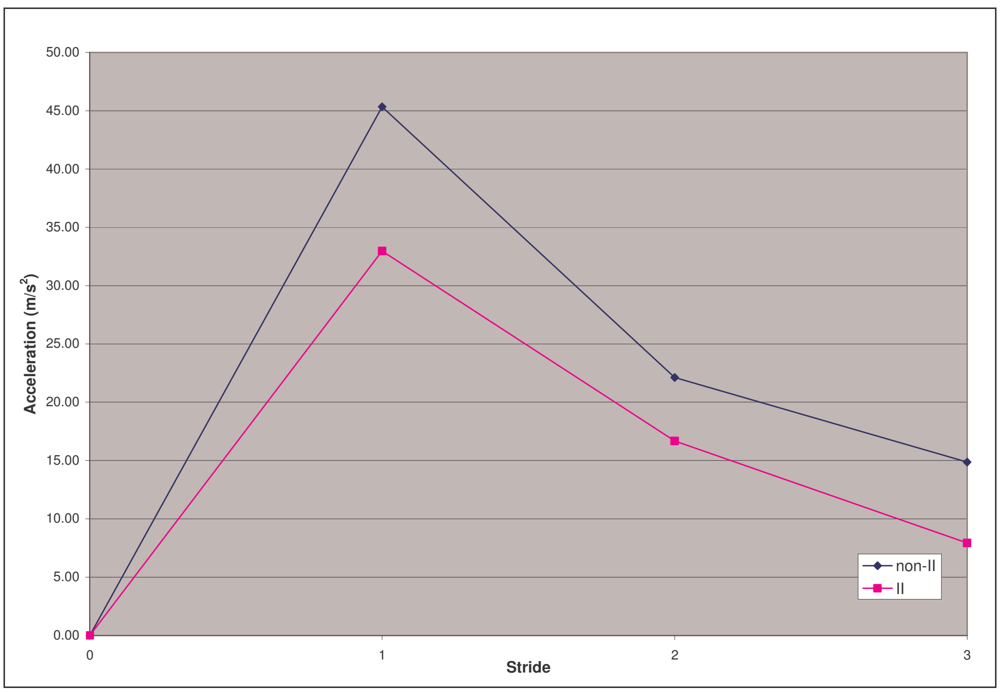

Figure 30

A comparison between non-II and II athletes in terms of stride number and mean overall acceleration per stride covered from the 20m point for the next three strides

Mean Acceleration from the 20m point for the Next Three Strides

The mean overall acceleration from the 20m point for the next three strides of the athletes from the two groups is presented in Table 33.

Table 33

Difference in mean stride acceleration from the 20m point for the next three strides

Athletes	df	Mean ($m.s^{-2}$)	SD	t	Sig. (2-tail)
Non-II	13	29.59	2.75	4.267	0.000
II	22	23.55	4.83		

From the data in the table it can be seen that there is a significant difference between non-II and II athletes. Figure 31 presents a visual comparison of the mean stride acceleration.

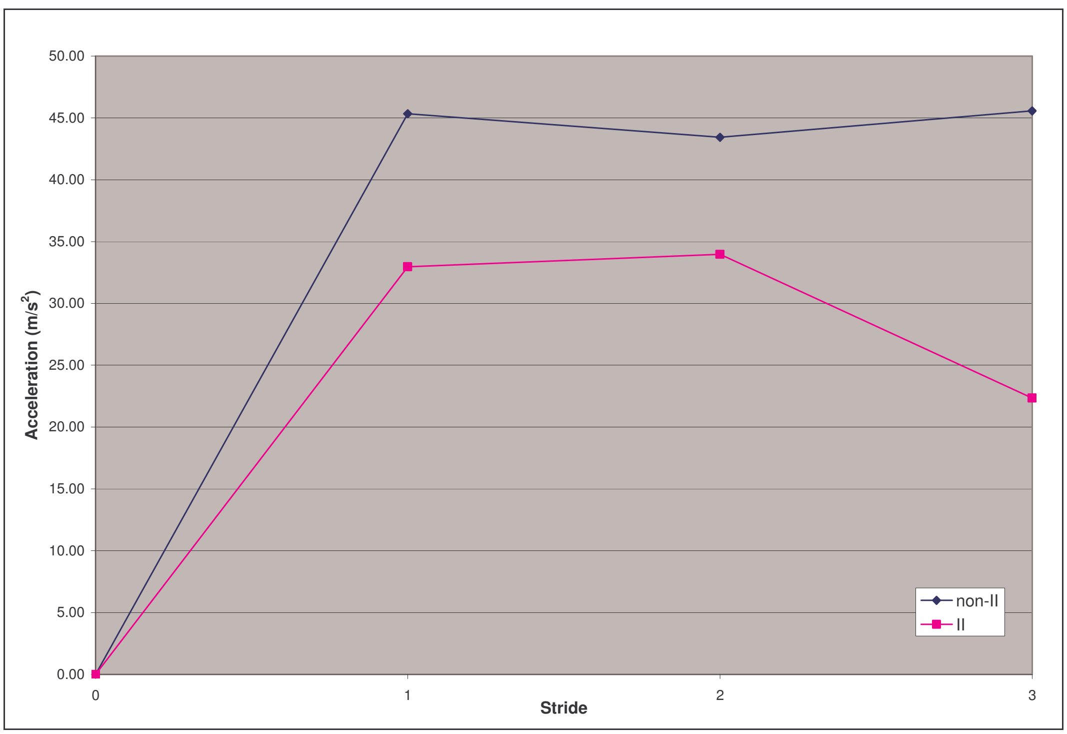

Figure 31

A comparison between non-II and II athletes with regard to the stride number and mean stride acceleration per stride from the 20m point for the next three strides

Summary

The answers to all three research questions were the same. Non II and II athletes were similar on the following characteristics of the acceleration phase of their sprinting:

1. Overall time.
2. Mean stride time.
3. Stride frequency.

Non II and II athletes were significantly different on the following characteristics of the acceleration phase of their sprinting:

1. Overall distance.
2. Mean stride length.
3. Overall velocity.
4. Mean velocity.
5. Overall acceleration.
6. Mean acceleration.

When put in the context of Hay's (1978) framework, it appears that stride length is the source of the difference between the sprinting speeds of intellectually impaired athletes compared to non-intellectually impaired athletes (see Figure 32). Possible reasons for this significant difference will be presented in the next chapter.

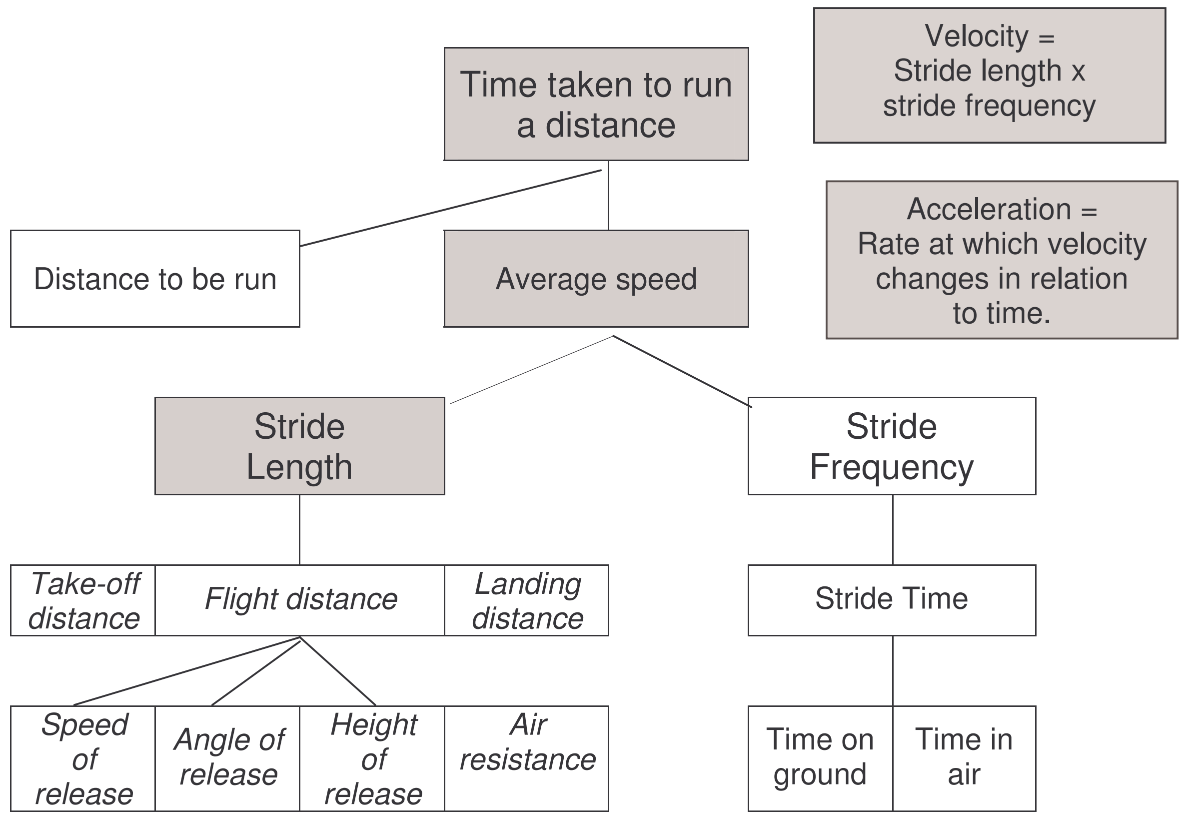

Figure 32

Shaded areas in Hay's 1978 framework identifying the significant differences between the sprinting of non II and II athletes.

Chapter Five

Discussion and Conclusion

The sprinting performances of II athletes were found to be significantly different from the performances of non-II athletes in every phase of the sprint, based on differences found in the following variables:

1. **Mean stride length** was significantly shorter for every stride in every phase of the sprint for the II athletes, which meant that **overall distance covered in each phase** of the sprint was also significantly less for the II athletes.

2. Velocity was significantly less (**overall velocity** and **mean velocity** of the II athletes were significantly less).

3. Acceleration was significantly less (**overall acceleration** and **mean acceleration** of the II athletes were significantly slower).

The differences in velocity and acceleration can be attributed to the shorter stride length of the II athletes, because both velocity and acceleration are the products of time and distance, and time was found to be similar between the II and non-II athletes.

The II athletes did not run as fast as the non-II athletes. Because overall running speed is the product of stride length and stride frequency, and stride frequency was identified as the source of the difference, a closer look at stride length is necessary. The most common reasons for stride length differences among sprinters are differences in leg length and range of movement in the hip joints (Hay, 1978). Unfortunately, this information was not available on the athletes in this study. However, data were available on the heights of the subjects, which is relevant to stride length for sprinters. MacKenzie (2007) cited research in which optimal stride length was determined by height (m) x 1.35 in one study, and height (m) x 1.14 in another. For the II athletes in this study, average height was 167±10cm and for the non-II athletes it was 171±6cm. This average difference of approximately four centimetres in height could be a factor in stride length difference.

Physical Sources for Differences

Previous studies have identified some physical variables that may help explain differences in stride length (see Table 34).

Table 34

Differences in relevant variables that may affect stride length in II sprinters

Findings from Literature about II individuals compared to non-II individuals	Possible Implications for Sprinting and Stride Length
Weaker in the strength of elbow and knee extension and flexion (Horvat *et al.*,1997; Pitetti & Yarmer, 2002).	1. Diminished toe-off push due to the weaker knee strength. 2. Reduced leg drive because of the diminished toe-off. 3. Shorter stride length because of the reduced leg drive and diminished toe-off.
Differences in speed of limb movement, explosive strength and flexibility (Lefevre *et al.*,2000).	1. Slower sprinting speed of the athlete because of slower limb movement speed. 2. Shorter stride length due to less explosive strength and/or flexibility.
Children show diminished fundamental and complex motor skill development (Shapiro & Dummer, 1998). Lower levels of motor proficiency found among II individuals in general (Dobbins & Rarick, 1977; Londeree & Johnson, 1974).	1. Poor running form developed during childhood could limit the ability of the athlete to achieve a mature and efficient running pattern as an adult. 2. Shorter stride length because of the poor running form could become automated, thus affecting adult stride length.
Diminished development of normal balance (Rider & Abdulahad, 1991). Reduced long jump performance attributed to less effective balance control (Di Rocco *et al.*, 1987). Reduced balance control associated with less efficient generation horizontal and/or vertical ground forces (Di Rocco *et al.*, 1987).	1. Reduced balance control could lead to compensatory movements, e.g. shorter arm swing, that could limit the ability of the athlete to achieve a mature and efficient running pattern as an adult. 2. Most common adjustment would probably be shorter stride length to compensate for reduced balance control.

Although the differences between II and non-II individuals in terms of fitness variables cannot be disregarded, the evidence is not compelling. For example, there is other evidence that suggests that the fitness of II athletes is similar to the fitness of active non-II individuals (Van de Vliet *et al.,* 2006). However, the finding that many II individuals manifest reduced balance control is very interesting (Rider & Abdulahad, 1991). Balance control – both static and dynamic - is a critical underlying ability upon which most other abilities and skills are built (Burton & Davis, 1992). Reduced balance control could partially account for diminished development of fundamental and complex motor skills (*i.e*. less efficient movement patterns), as well as specifically account for shorter stride length.

Coaching as a Source for Differences

In order to develop a valid classification system, it is necessary to identify those measurable physical variables that can define legitimate sources for the differences in performance between II athletes and non-II athletes. However, Hoover and Wade (1985) noted that there has been so much certainty in the scientific and educational communities that II individuals have a “deficit” somewhere in their information processing capabilities, that insufficient effort has gone into developing teaching and training strategies. In fact, they suggested that a limiting variable on the achievement of II individuals is the assumption by their teachers and coaches that they will not be able to attain the same levels of performance as non-II individuals.

How does this relate to differences in stride length? No data was gathered from the athletes in this study regarding their sprint training, so it is not known if they had quality sprint coaching. Stride length, for example, is specifically trained. Coaches work with athletes on improving three different components in order to help optimize stride length (Fortner, 2007):

1. Strengthen the leg muscles.

   By improving the strength in the leg muscles, athletes will be able to produce a stronger push-off from the track that will drive the athlete further and help them maintain their momentum better. Ways for coaches to promote improvements in their athlete's leg strength would involve plyometric (jumping) activities, hill work, speed work, and leg concentrated gym work.

2. Increase flexibility.

   Coaches should include stretching as an integral part of training. Not only does it help athletes to avoid injuries but it can also help make athletes faster by enabling a longer stride length. The longer an athlete's foot remains in contact with the ground before toe-off, the longer the athlete's stride length. In turn, the maximum angle that an athlete's ankle and hip can achieve in a stride limit how long the athlete's foot can remain on the ground. These maximum angles are largely determined by the flexibility of the leg muscles, ankles and hip flexors. Stretching will increase the flexibility of all of these, enabling an extended foot contact and resulting in a later push-off more from an athlete's toes than from the ball of the foot, thus, a longer stride length.

3. Improve the athlete's running form.

   The key here is for the coach to get their athletes keep their centre of gravity forward, especially at their hips. Coaches must however stress that athletes must try to be erect when running with no forward bend at the waist. Eyes should be looking straight ahead.

   It is important that while trying to help their athletes achieve a longer stride length, coaches do not let them over stride because this will lead to a braking action which will actually slow the athletes down.

According to Hoover and Wade (1985), if coaches believe their athletes can only achieve a certain level, then their athletes will only achieve that level and no better. If this is the case then II athletes might not be running to their own potential, but rather to the potential that their coaches believe they have. This means that coaching strategies must change if we are to ever discover the sport potential of the II athlete. If the performance gap between the II and the non-II athletes can be closed, it may mean that there does not need to be a special classification for sprinting at the elite level.

Recommendations for Research

In terms of future research on sprinting using video analysis, several suggestions for future research are made:

1. Cameras should be placed to record every 5m of the sprint and not every 10m as in this study. Each camera would then be closer to the athletes, which would produce a larger image. A larger image would make kinematic analysis much easier and more accurate, since the exact movements of the limbs would be easier to see.

2. Higher frequency (a minimum of 100hrz cameras should be used) cameras should be used to produce more frames per second which produces a clearer image. For example, with more frames per second, details about foot placement can be seen.

3. This study did not analyse the arm action or the postural position of the sprinters. Research that includes an evaluation of these two variables would contribute to our understanding of the role of balance control in performance, since both arm actions and postural adjustments are indicators of difficulties with balance control.

4. The use of force plates, particularly in the starting blocks, would provide valuable information about possible differences in force generation between the two groups. Differences in force generation could be the result of differences in either explosive power or total body coordination. A comparison could also be made for each sprinter to determine if the II athletes create similar force with both their right and left legs. Symmetry in force generation is an indicator of total body coordination (Magill, 2003).

The possibility that balance control might be a limiting physical factor in the sport performance of II athletes leads to the need to focus additional research in the direction of identifying measurable and observable variables that may impact performance.

1. Balance control requires much more study since it is an underlying ability that support performance of all movement activities. Magill (2003) specified that dynamic and static balance must be regarded as separate variables, so research should focus on the measurement of both.

2. If stride length is a limiting variable, then additional research into 100m, 200m and 400m would provide further insight into the impact of this limitation on sprinting performance. At longer distances (*e.g.* 800m upwards) a shorter stride length is used by non-II athletes, so the importance of differences in stride length starts to diminish. Does this mean that performance of II athletes should match that of non-II athletes, or do new factors come into play that have a negative impact on performance?

3. Intervention programmes that attempt to improve the performances of II athletes with specific training methods would help define whether or not coaching methods are a limiting factor on performance potential. Hoover and Wade (1985) believed that they may be, but noted that they are not sure how one would go about studying this situation in a systematic way. They concluded that because the ways in which II individuals learn and process information is not understood, research on education and training intervention programmes is difficult. They called for a concerted effort to understand how II individuals learn in general, before making conclusions about their potential to learn and perform.

The analysis of the data by gender is an obvious direction for future research, since information about physical performance is often gender-specific. Although classification for disability sport does not use gender categories at this time, the value of such analyses for coaches and trainers could be very important.

Insight into Classification

The overall purpose of this study was to expand our knowledge of possible differences in the performances of II athletes and non-II athletes in order to gain insight into the challenge of creating a valid classification system. A single study cannot determine with certainty what the differences are or what causes those differences, but the fact that there was a significant difference found in stride length leads to the following thoughts.

1. If in further research it is found that significant differences exist in stride length between II and non-II athletes in other performance contexts, then the physical determinants of stride length, such as balance control, should be included in the sport classification of II athletes.

2. If, however, there is no recurring pattern of differences in stride length between the two groups in other contexts, then the physical determinants of stride length, including balance control, should be considered for inclusion in classification specifically for sprinting events.

3. In order to address the challenge of resolving protests regarding classification during competitions, digital video records of II athletes can be made during competition and analysed if there is a protest. For example, if stride length has been identified as a characteristic for classification and a protest is filed regarding the participation of an II sprinter, his/her sprint performance could be analysed to determine whether his/her stride length exceeded the range acceptable for II sprinters. It is clear from this example that there are substantial challenges ahead facing a valid classification system for II athletes.

If research finds no recurring observable and measurable factors that characterise the sport performances of II athletes, then the challenge to develop a classification system appears overwhelming. If it is found that it is not physical factors, but rather coaching or other environmental factors, much more research will need to be done. If Hoover and Wade (1985) are correct, coaches cannot simply be told to train their II athletes in the same way they do their non-

II athletes. They must be given new approaches to training based on new insights about how individuals with intellectual impairments learn.

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Appendix A

Camera 1 – Start Data

Table A1

Difference between non-II and II athletes with regard to the overall time taken from the start for the first seven strides

	Overall Time	
Subject	**Non-II**	**II**
1	2.34	1.83
2	2.04	1.64
3	2.02	1.85
4	1.64	1.69
5	1.68	1.70
6	1.96	1.48
7	1.94	1.86
8	1.94	1.56
9	1.86	2.00
10	1.68	2.03
11	1.90	1.91
12	2.08	2.09
13	1.88	2.14
14	1.86	1.95
15		1.98
16		1.97
17		1.92
18		1.91
19		2.19
20		2.10
21		2.02
22		2.17
23		2.41

Table A2

Differences between non-II and II athletes with regard to mean overall time per stride taken from the start for the first seven strides

Stride	Non-II Time (Seconds)	II Time (Seconds)	Difference
0	0.00	0.00	0.00
1	0.72	0.71	0.01
2	0.96	0.99	-0.03
3	1.21	1.24	-0.03
4	1.43	1.49	-0.06
5	1.67	1.74	-0.07
6	1.90	1.90	0.00
7	2.09	2.06	0.03

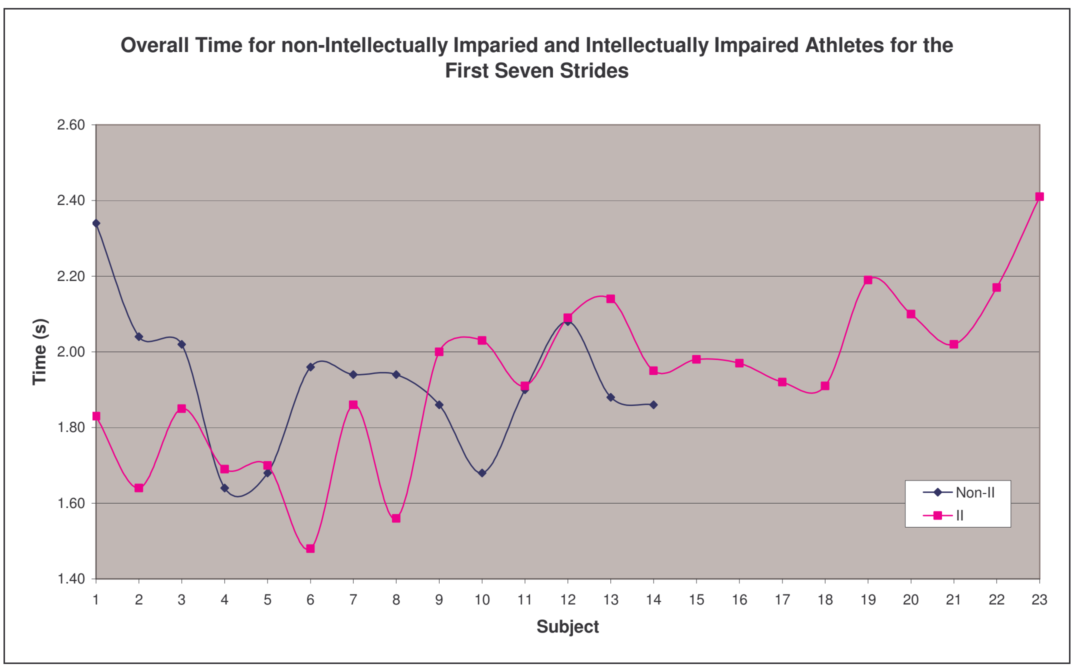

Figure A1

Showing the difference between non-II and II athletes with regard to the overall time taken from the start for the first seven strides

Table A3

Difference between non-II and II athletes stride length with regard to the overall distance covered from the start for the first seven strides

	Overall Distance	
Subject	**Non-II**	**II**
1	10.51	7.37
2	10.03	6.46
3	9.25	7.22
4	8.33	7.25
5	7.86	6.12
6	7.57	6.13
7	8.72	7.05
8	8.25	6.77
9	8.66	7.87
10	7.85	7.68
11	9.21	7.35
12	9.35	7.66
13	9.21	7.94
14	8.86	6.89
15		7.45
16		5.96
17		6.65
18		7.57
19		6.45
20		5.91
21		6.02
22		6.80
23		6.76

Table A4

Difference between non-II and II athletes with regard to the mean overall distance per stride covered from the start for the first seven strides

Stride	Non-II Distance (Meters)	II Distance (Meters)	Difference
0	0.00	0.00	0.00
1	0.95	0.69	0.26
2	2.17	1.80	0.37
3	3.64	3.04	0.60
4	5.20	4.39	0.81
5	6.92	5.80	1.12
6	8.71	6.88	1.83
7	10.17	7.24	2.93

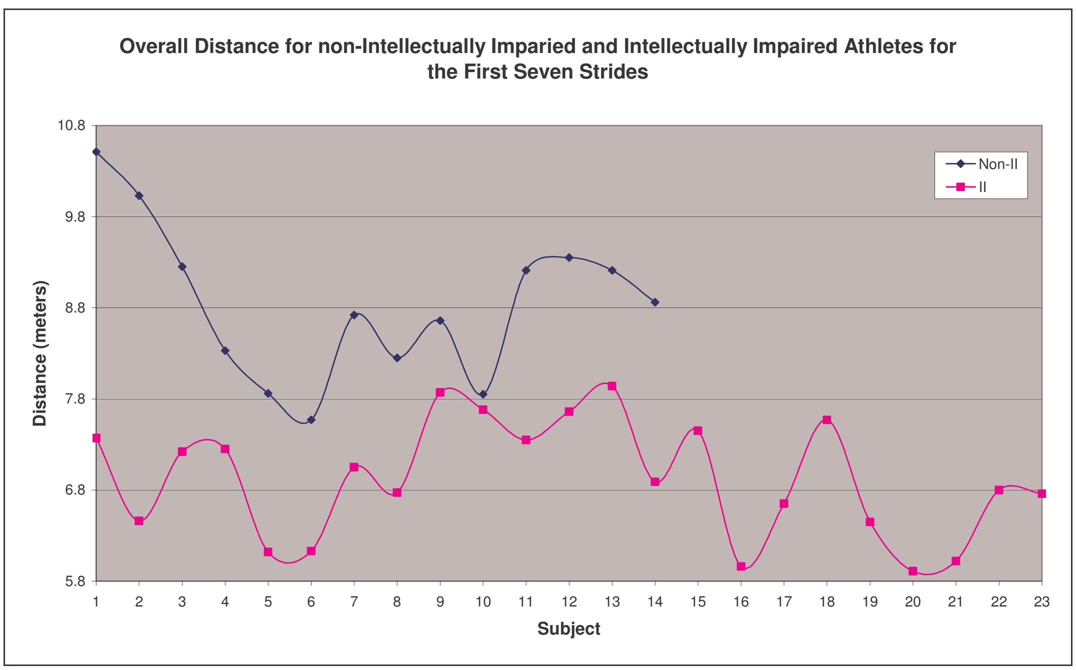

Figure A2

Showing the difference between non-II and II athletes with regard to the overall distance covered from the start for the first seven strides

Table A5

Difference between non-II and II stride length with regard to the overall velocity obtained from the start for the first seven strides

	Overall Velocity	
Subject	**Non-II**	**II**
1	4.49	4.03
2	4.92	3.93
3	4.58	3.91
4	5.08	4.28
5	4.68	3.61
6	3.86	4.13
7	4.49	3.78
8	4.25	4.35
9	4.66	3.93
10	4.67	3.78
11	4.85	3.84
12	4.50	3.67
13	4.90	3.71
14	4.76	3.53
15		3.77
16		3.03
17		3.47
18		3.97
19		2.95
20		2.82
21		2.98
22		3.14
23		2.81

Table A6

Difference between non-II and II athletes with regard to the mean overall velocity per stride covered from the start for the first seven strides

Stride	Non-II Velocity ($m.s^{-1}$)	II Velocity ($m.s^{-1}$)	Difference
0	0.00	0.00	0.00
1	1.34	0.96	0.38
2	2.26	1.84	0.42
3	3.02	2.48	0.54
4	3.64	2.96	0.68
5	4.15	3.36	0.79
6	4.60	3.65	0.95
7	4.89	3.59	1.30

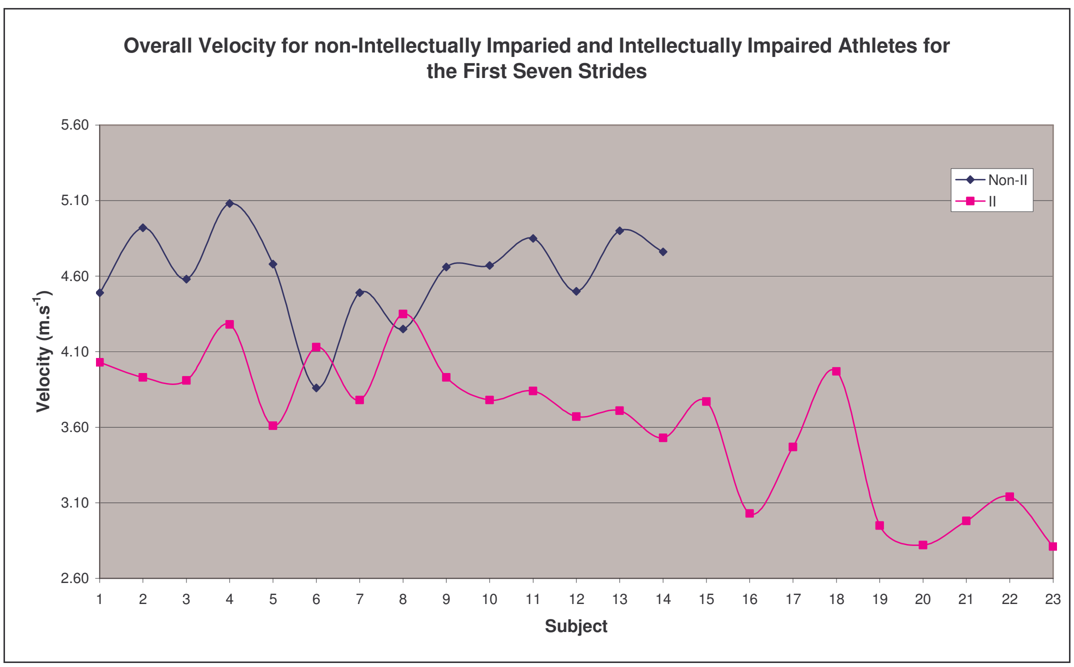

Figure A3

Showing the difference between non-II and II athletes with regard to the overall velocity obtained from the start for the first seven strides

Table A7

Difference between non-II and II stride length with regard to the overall acceleration obtained from the start for the first seven strides

	Overall Acceleration	
Subject	**Non-II**	**II**
1	1.92	2.21
2	2.41	2.39
3	2.27	2.11
4	3.10	2.53
5	2.78	2.12
6	1.97	2.78
7	2.32	2.03
8	2.19	2.80
9	2.50	1.96
10	2.78	1.86
11	2.55	2.01
12	2.16	1.76
13	2.61	1.73
14	2.56	1.81
15		1.91
16		1.54
17		1.81
18		2.08
19		1.35
20		1.34
21		1.48
22		1.45
23		1.17

Table A8

Difference between non-II and II athletes with regard to the mean overall acceleration per stride covered from the start for the first seven strides

Stride	Non-II Acceleration ($m.s^{-2}$)	II Acceleration ($m.s^{-2}$)	Difference
0	0.00	0.00	0.00
1	1.94	1.42	0.52
2	2.39	1.95	0.44
3	2.54	2.06	0.48
4	2.56	2.04	0.52
5	2.51	1.98	0.53
6	2.44	1.96	0.48
7	2.37	1.83	0.54

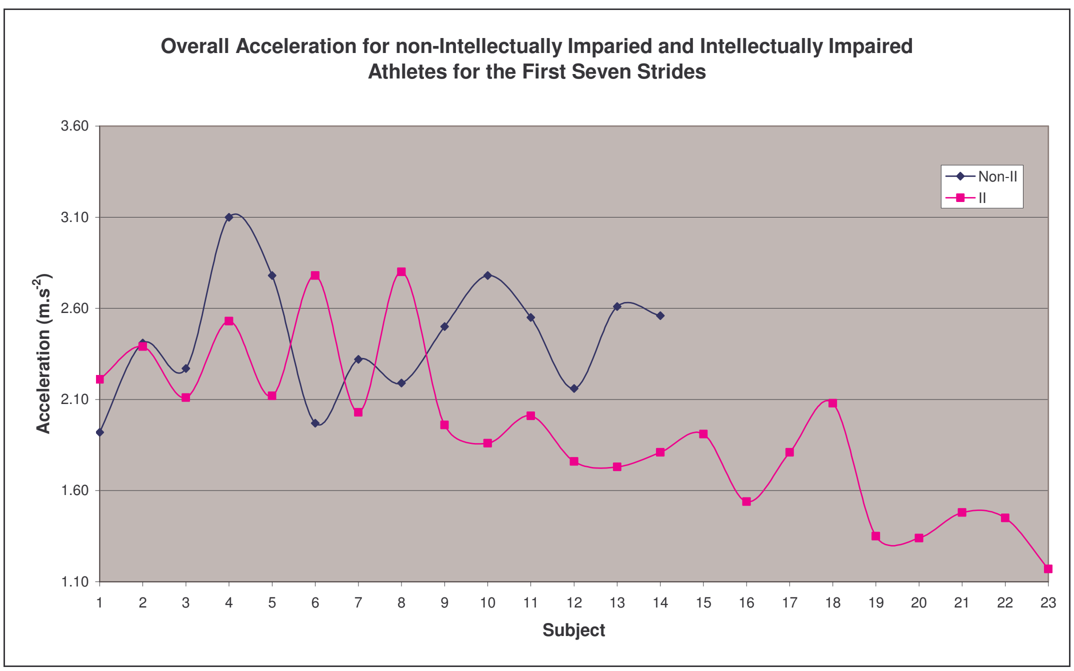

Figure A4

Showing the difference between non-II and II athletes with regard to the overall acceleration obtained from the start for the first seven strides

Table A9

Difference between non-II and II athletes with regard to the mean stride time taken from the start for the first seven strides

	Mean Stride Time	
Subject	**Non-II**	**II**
1	0.29	0.26
2	0.29	0.21
3	0.29	0.26
4	0.23	0.24
5	0.24	0.24
6	0.28	0.21
7	0.28	0.27
8	0.28	0.22
9	0.27	0.29
10	0.24	0.29
11	0.27	0.27
12	0.30	0.30
13	0.27	0.31
14	0.27	0.28
15		0.28
16		0.28
17		0.27
18		0.27
19		0.31
20		0.30
21		0.29
22		0.31
23		0.34

Table A10

Difference between non-II and II athletes with regard to the mean stride time per stride covered from the start for the first seven strides

Stride	Non-II Stride Time (Seconds)	II Stride Time (Seconds)	Difference
0	0.00	0.00	0.00
1	0.72	0.71	0.01
2	0.25	0.27	-0.02
3	0.24	0.25	-0.01
4	0.23	0.25	-0.02
5	0.24	0.25	-0.01
6	0.23	0.23	0.00
7	0.23	0.22	0.01

Figure A5

Showing the difference between non-II and II athletes with regard to the mean stride time taken from the start for the first seven strides

Table A11

Difference between non-II and II athletes with regard to the mean stride length covered from the start for the first seven strides

	Mean Stride Length	
Subject	**Non-II**	**II**
1	1.31	1.05
2	1.43	0.81
3	1.32	1.03
4	1.19	1.04
5	1.12	0.87
6	1.08	0.88
7	1.25	0.95
8	1.18	0.97
9	1.24	1.12
10	1.12	1.10
11	1.32	1.05
12	1.34	1.09
13	1.32	1.13
14	1.27	0.98
15		1.06
16		0.85
17		0.95
18		1.08
19		0.92
20		0.84
21		0.86
22		0.97
23		0.97

Table A12

Difference between non-II and II athletes with regard to the mean stride length per stride covered from the start for the first seven strides

Stride	Non-II Stride Length (Meters)	II Stride Length (Meters)	Difference
0	0.00	0.00	0.00
1	0.95	0.69	0.26
2	1.21	1.11	0.10
3	1.47	1.24	0.23
4	1.57	1.35	0.22
5	1.71	1.41	0.30
6	1.79	1.39	0.40
7	1.76	1.30	0.46

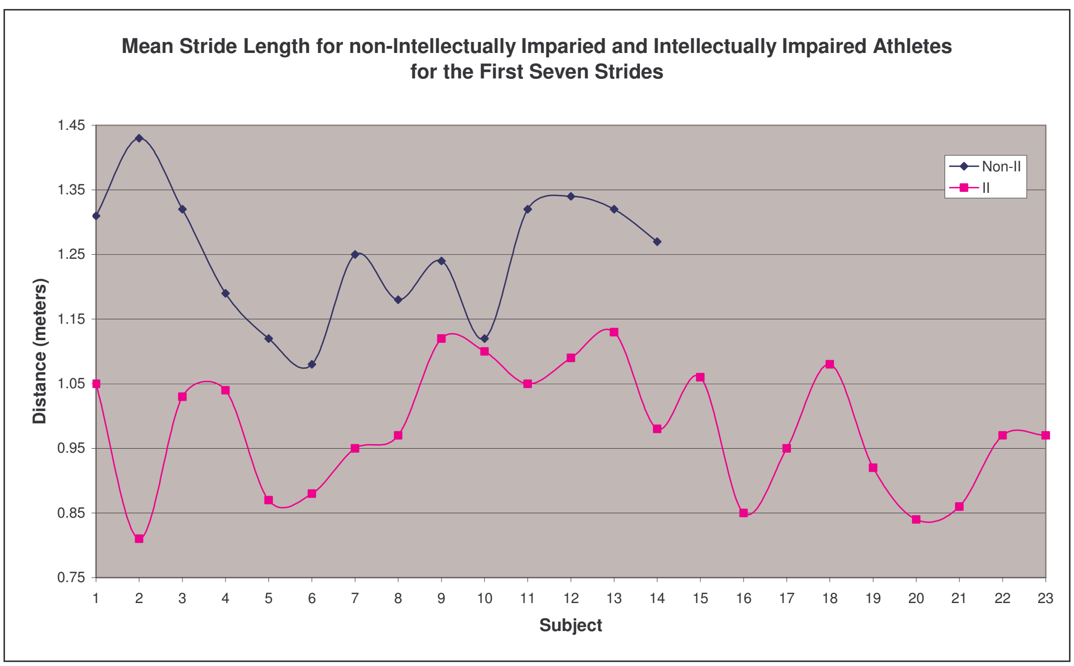

Figure A6

Showing the difference between non-II and II athletes with regard to the mean stride length covered from the start for the first seven strides

Table A13

Difference between non-II and II athletes with regard to the mean stride velocity obtained from the start for the first seven strides

	Mean Stride Velocity	
Subject	**Non-II**	**II**
1	4.94	4.39
2	5.34	3.89
3	4.98	4.51
4	4.88	4.21
5	5.00	3.76
6	4.23	4.09
7	4.93	3.74
8	4.50	4.01
9	4.97	4.24
10	5.01	4.23
11	5.09	4.07
12	5.14	3.98
13	5.11	4.11
14	4.98	3.94
15		3.86
16		3.38
17		3.65
18		3.78
19		3.47
20		3.16
21		3.15
22		3.22
23		3.02

Table A14

Difference between non-II and II athletes with regard to the mean stride velocity per stride covered from the start for the first seven strides

Stride	Non-II Stride Velocity ($m.s^{-1}$)	II Stride Velocity ($m.s^{-1}$)	Difference
0	0.00	0.00	0.00
1	1.34	0.96	0.38
2	4.92	4.13	0.79
3	6.03	4.96	1.07
4	6.93	5.38	1.55
5	7.27	5.76	1.51
6	7.89	5.96	1.93
7	7.69	5.91	1.78

Figure A7

Showing the difference between non-II and II athletes with regard to the mean stride velocity obtained from the start for the first seven strides

Table A15

Difference between non-II and II athletes with regard to the mean stride acceleration obtained from the start for the first seven strides

	Mean Stride Acceleration	
Subject	**Non-II**	**II**
1	19.62	19.19
2	21.71	19.03
3	20.11	21.13
4	20.71	17.62
5	23.22	16.58
6	17.28	19.60
7	20.78	15.83
8	17.86	16.79
9	21.27	16.73
10	23.40	17.27
11	20.57	16.61
12	20.91	15.27
13	20.79	15.88
14	20.59	16.68
15		14.40
16		13.95
17		14.77
18		13.69
19		13.79
20		12.36
21		12.16
22		11.08
23		9.93

Table A16

Difference between non-II and II athletes with regard to the mean stride acceleration per stride covered from the start for the first seven strides

Stride	Non-II Step Acceleration ($m.s^{-2}$)	II Step Acceleration ($m.s^{-2}$)	Difference
0	0.00	0.00	0.00
1	1.94	1.42	0.52
2	20.02	15.65	4.37
3	24.87	20.12	4.75
4	30.91	21.89	9.02
5	31.07	23.94	7.13
6	34.83	25.80	9.03
7	33.80	27.01	6.79

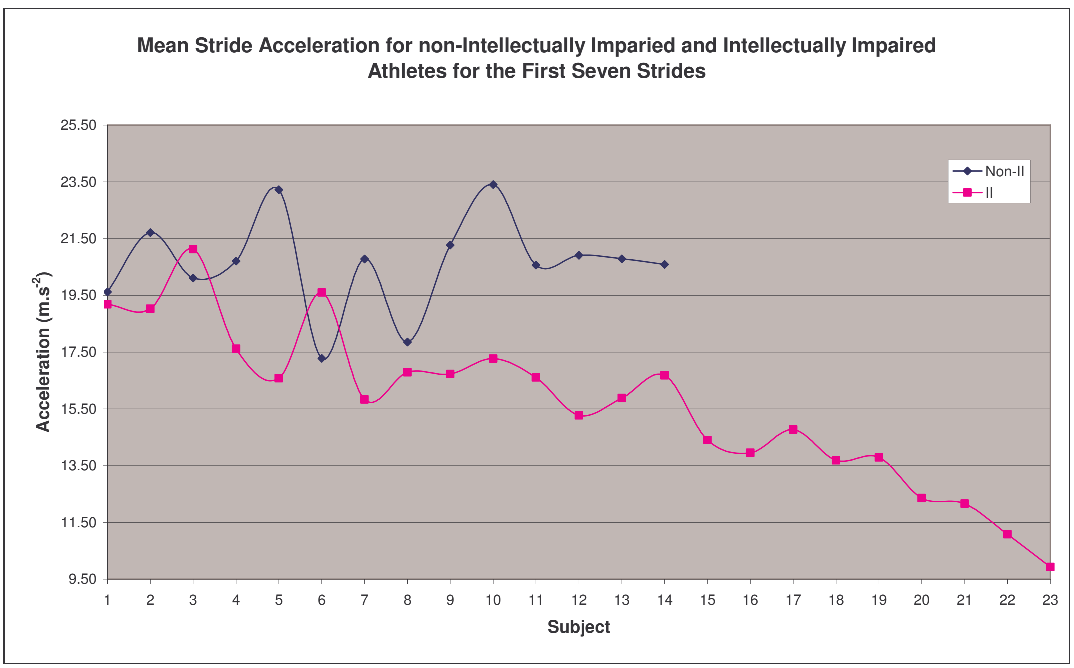

Figure A8

Showing the difference between non-II and II athletes with regard to the mean stride acceleration obtained from the start for the first seven strides

Table A17

Difference between non-II and II athletes with regard to the stride frequency from the start for the first seven strides

	Stride Frequency	
Subject	**Non-II**	**II**
1	205.13	196.72
2	176.47	260.87
3	178.22	194.59
4	225.81	213.02
5	223.40	211.80
6	190.91	248.50
7	192.66	193.50
8	194.44	230.77
9	200.00	180.00
10	223.40	177.34
11	196.26	188.48
12	173.08	172.25
13	191.49	168.22
14	198.11	184.62
15		181.82
16		191.78
17		188.48
18		188.48
19		174.27
20		179.49
21		178.22
22		165.90
23		149.38

Appendix B

Camera 2 – 10m Data

Table B1

Difference between non-II and II athletes with regard to the overall time taken from the 10m point for the next four strides

	Overall Time	
Subject	**Non-II**	**II**
1	0.70	0.61
2	0.66	0.57
3	0.68	0.65
4	0.66	0.66
5	0.64	0.67
6	0.68	0.62
7	0.66	0.68
8	0.68	0.63
9	0.70	0.70
10	0.64	0.73
11	0.68	0.71
12	0.70	0.67
13	0.70	0.71
14	0.72	0.65
15		0.74
16		0.66
17		0.70
18		0.74
19		0.68
20		0.73
21		0.80
22		0.80
23		0.85

Table B2

Difference between non-II and II athletes with regard to the mean overall time per stride taken from the 10m point for the next four strides

Stride	Non-II Time (Seconds)	II Time (Seconds)	Difference
0	0.00	0.00	0.00
1	0.23	0.24	-0.01
2	0.45	0.49	-0.04
3	0.68	0.72	-0.04
4	0.91	0.99	-0.08

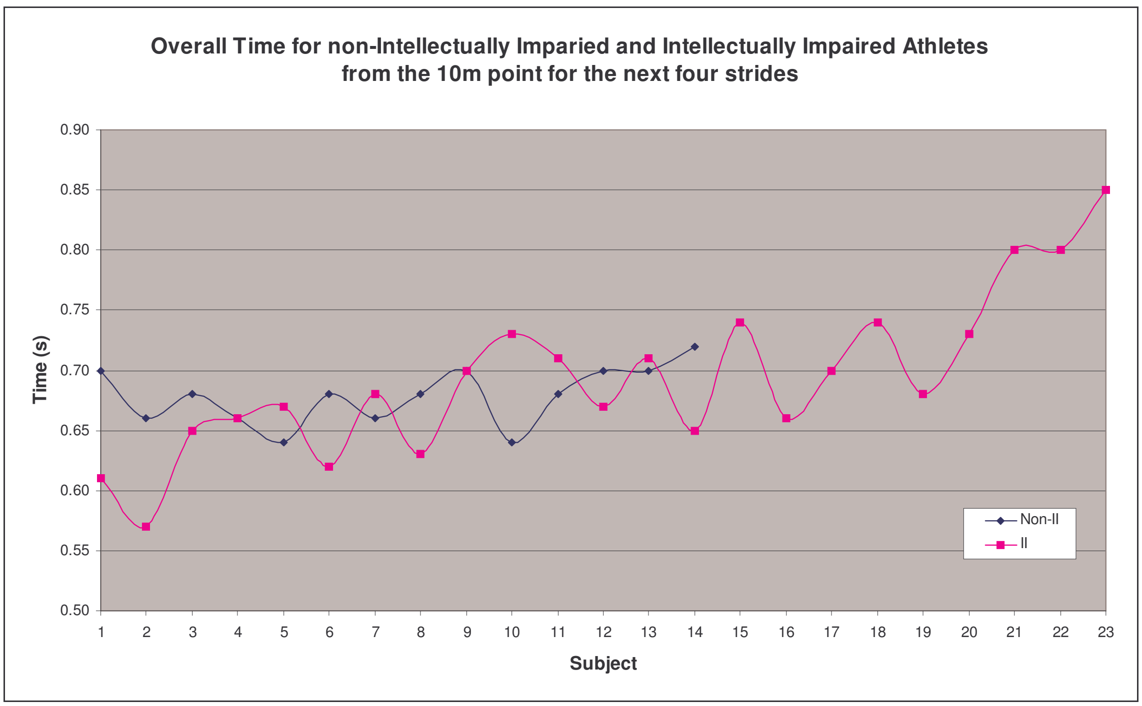

Figure B1

Showing the difference between non-II and II athletes with regard to the overall time taken from the 10m point for the next four strides

Table B3

Difference between non-II and II athletes stride length with regard to the overall distance covered from the 10m point for the next four strides

	Overall Distance	
Subject	**Non-II**	**II**
1	5.52	5.21
2	6.14	4.62
3	5.91	5.27
4	5.72	5.42
5	5.93	5.21
6	5.69	4.83
7	6.12	5.18
8	5.95	5.00
9	6.09	5.34
10	5.85	5.59
11	6.34	5.47
12	6.40	5.30
13	6.25	5.43
14	6.38	4.91
15		5.46
16		4.67
17		4.88
18		5.25
19		4.94
20		4.86
21		4.69
22		4.94
23		4.44

Table B4

Difference between non-II and II athletes with regard to the mean overall distance per stride covered from the 10m point for the next four strides

Stride	Non-II Distance (Meters)	II Distance (Meters)	Difference
0	0.00	0.00	0.00
1	1.93	1.70	0.23
2	3.94	3.44	0.50
3	6.02	5.08	0.94
4	8.09	6.31	1.78

Figure B2

Showing the difference between non-II and II athletes with regard to the overall distance covered from the 10m point for the next four strides

Table B5

Difference between non-II and II athletes stride length with regard to the overall velocity obtained from the 10m point for the next four strides

	Overall Velocity	
Subject	**Non-II**	**II**
1	7.89	8.50
2	9.30	8.14
3	8.69	8.22
4	8.67	8.22
5	9.27	7.81
6	8.37	7.82
7	9.27	7.57
8	8.75	7.94
9	8.70	7.62
10	9.14	7.62
11	9.32	7.67
12	9.14	7.94
13	8.93	7.66
14	8.86	7.55
15		7.35
16		7.09
17		6.96
18		7.11
19		7.22
20		6.62
21		5.86
22		6.14
23		5.22

Table B6

Difference between non-II and II athletes with regard to the mean overall velocity per stride covered from the 10m point for the next four strides

Stride	Non-II Velocity ($m.s^{-1}$)	II Velocity ($m.s^{-1}$)	Difference
0	0.00	0.00	0.00
1	8.47	7.06	1.41
2	8.72	7.18	1.54
3	8.88	7.18	1.70
4	8.94	6.59	2.35

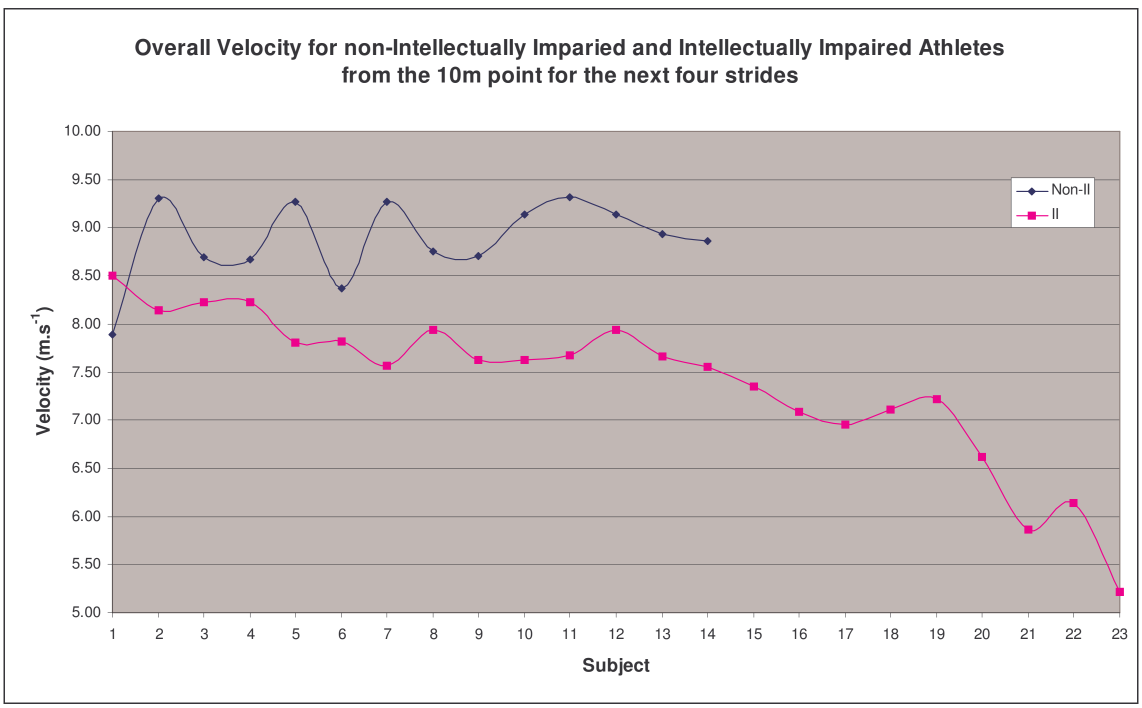

Figure B3

Showing the difference between non-II and II athletes with regard to the overall velocity obtained from the 10m point for the next four strides

Table B7

Difference between non-II and II athletes stride length with regard to the overall acceleration obtained from the 10m point for the next four strides

	Overall Acceleration	
Subject	**Non-II**	**II**
1	11.27	13.86
2	14.10	14.35
3	12.78	12.48
4	13.13	12.48
5	14.48	11.70
6	12.31	12.68
7	14.05	11.07
8	12.87	12.61
9	12.43	10.88
10	14.28	10.37
11	13.71	10.75
12	13.06	11.90
13	12.76	10.80
14	12.31	11.60
15		9.91
16		10.75
17		9.94
18		9.63
19		10.56
20		9.02
21		7.31
22		7.62
23		6.13

Table B8

Difference between non-II and II athletes with regard to the mean overall acceleration per stride covered from the 10m point for the next four strides

Stride	Non-II Acceleration ($m.s^{-2}$)	II Acceleration ($m.s^{-2}$)	Difference
0	0.00	0.00	0.00
1	37.24	29.81	7.43
2	19.32	15.16	4.16
3	13.11	10.30	2.81
4	9.90	7.11	2.79

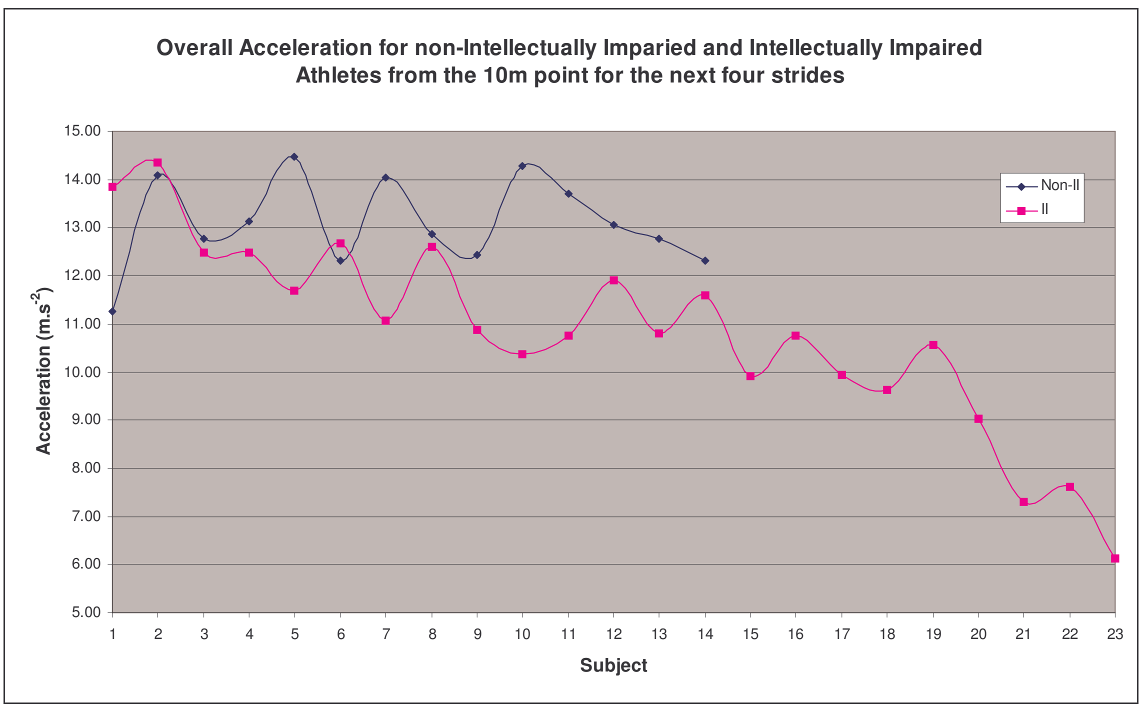

Figure B4

Showing the difference between non-II and II athletes with regard to the overall acceleration obtained from the 10m point for the next four strides

Table B9

Difference between non-II and II athletes with regard to the mean stride time taken from the 10m point for the next four strides

	Mean Stride Time	
Subject	**Non-II**	**II**
1	0.18	0.15
2	0.17	0.14
3	0.17	0.16
4	0.17	0.16
5	0.16	0.17
6	0.17	0.15
7	0.17	0.17
8	0.17	0.16
9	0.18	0.18
10	0.18	0.18
11	0.17	0.18
12	0.18	0.17
13	0.18	0.18
14	0.18	0.16
15		0.19
16		0.16
17		0.18
18		0.18
19		0.17
20		0.18
21		0.20
22		0.20
23		0.12

Table B10

Difference between non-II and II athletes with regard to the mean stride time per stride covered from the 10m point for the next four strides

Stride	Non-II Stride Time (Seconds)	II Stride Time (Seconds)	Difference
0	0.00	0.00	0.00
1	0.23	0.24	-0.01
2	0.22	0.24	-0.02
3	0.23	0.24	-0.01
4	0.23	0.25	-0.02

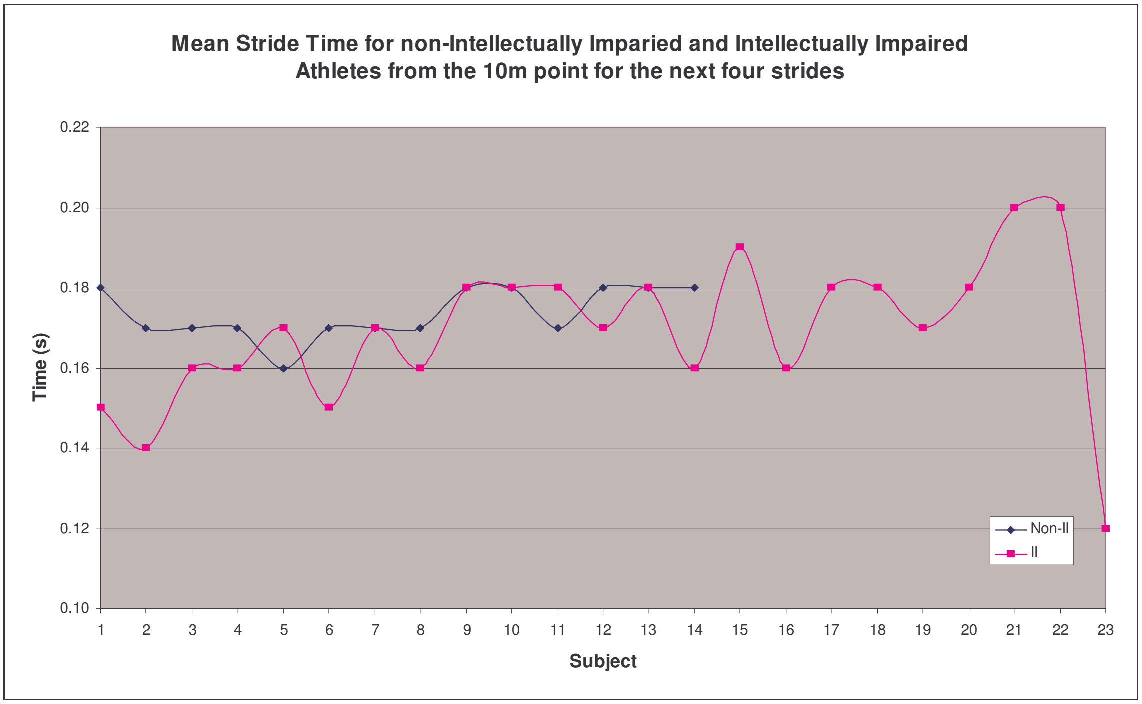

Figure B5

Showing the difference between non-II and II athletes with regard to the mean stride time taken from the 10m point for the next four strides

Table B12

Difference between non-II and II athletes with regard to the mean stride length covered from the 10m point for the next four strides

	Mean Stride Length	
Subject	**Non-II**	**II**
1	1.38	1.30
2	1.54	1.16
3	1.48	1.32
4	1.43	1.36
5	1.48	1.30
6	1.42	1.21
7	1.53	1.30
8	1.49	1.25
9	1.52	1.34
10	1.52	1.40
11	1.59	1.37
12	1.60	1.33
13	1.56	1.36
14	1.60	1.23
15		1.37
16		1.17
17		1.22
18		1.31
19		1.24
20		1.22
21		1.17
22		1.24
23		1.11

Table B13

Difference between non-II and II athletes with regard to the stride number and mean stride length per stride covered from the 10m point for the next four strides

Stride	Non-II Stride Length (Meters)	II Stride Length (Meters)	Difference
0	0.00	0.00	0.00
1	1.93	1.70	0.23
2	2.01	1.75	0.16
3	2.08	1.72	0.26
4	2.07	1.60	0.47

Figure B6

Showing the difference between non-II and II athletes with regard to the mean stride length covered from the 10m point for the next four strides

Table B7

Difference between non-II and II athletes with regard to the mean stride velocity obtained from the 10m point for the next four strides

	Average Step Velocity	
Subject	**Non-II**	**II**
1	5.92	6.37
2	7.02	6.12
3	6.53	6.07
4	6.50	6.19
5	6.97	5.86
6	6.28	5.87
7	6.95	5.71
8	6.58	5.95
9	6.53	5.72
10	6.53	5.71
11	7.00	5.76
12	6.85	5.96
13	6.71	5.75
14	6.68	5.66
15		5.52
16		5.32
17		5.24
18		5.33
19		5.43
20		4.97
21		4.39
22		4.60
23		3.92

Table B8

Difference between non-II and II athletes with regard to the stride number and mean stride velocity per stride covered from the 10m point for the next four strides

Stride	Non-II Stride Velocity ($m.s^{-1}$)	II Stride Velocity ($m.s^{-1}$)	Difference
0	0.00	0.00	0.00
1	8.47	7.06	0.59
2	9.00	7.31	1.69
3	9.22	7.31	1.89
4	9.15	6.72	2.43

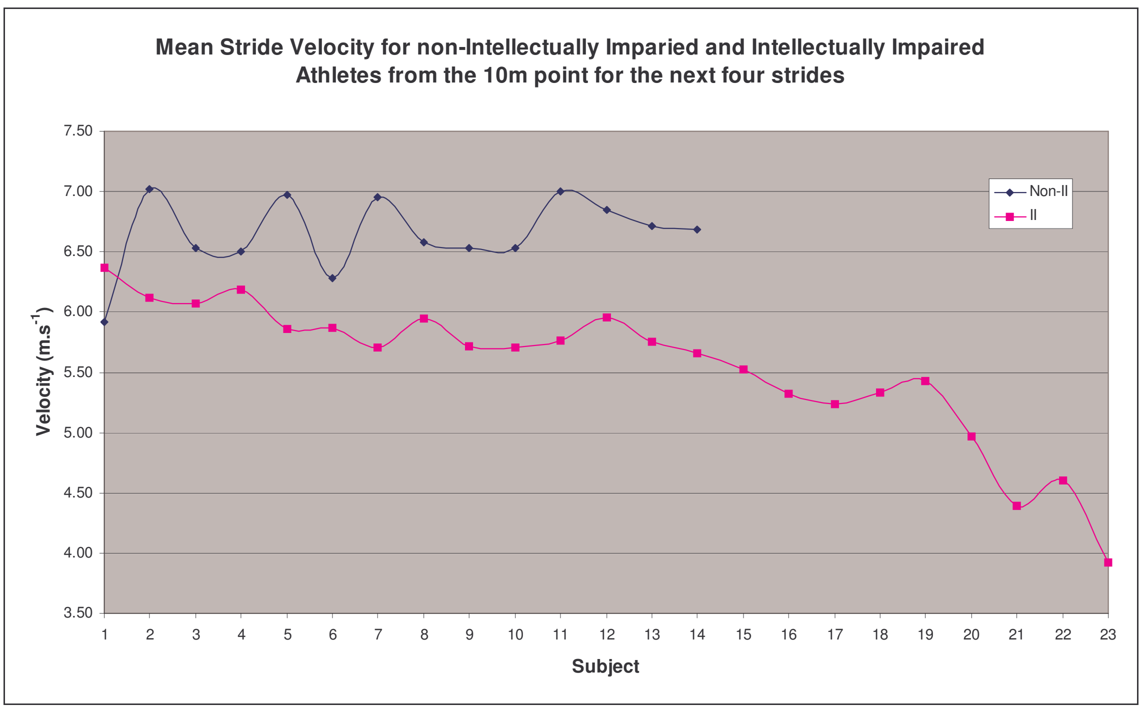

Figure B7

Showing the difference between non-II and II athletes with regard to the mean stride velocity obtained from the 10m point for the next four strides

Table B8

Difference between non-II and II athletes with regard to the mean stride acceleration obtained from the 10m point for the next four strides

	Mean Stride Acceleration	
Subject	**Non-II**	**II**
1	25.43	31.18
2	32.30	32.48
3	28.94	28.01
4	29.55	28.29
5	32.84	26.40
6	27.77	28.55
7	31.61	25.28
8	29.12	28.37
9	28.04	24.56
10	28.04	23.37
11	30.97	24.27
12	29.41	27.80
13	28.86	24.33
14	28.11	26.13
15		22.30
16		24.22
17		22.57
18		21.68
19		23.95
20		20.31
21		16.49
22		17.20
23		13.98

Table B9

Difference between non-II and II athletes with regard to the mean stride acceleration per stride covered from the 10m point for the next four strides

Stride	Non-II Step Acceleration ($m.s^{-2}$)	II Step Acceleration ($m.s^{-2}$)	Difference
0	0.00	0.00	0.00
1	37.24	29.81	7.43
2	40.48	31.05	9.43
3	40.94	31.40	9.54
4	40.57	29.29	11.28

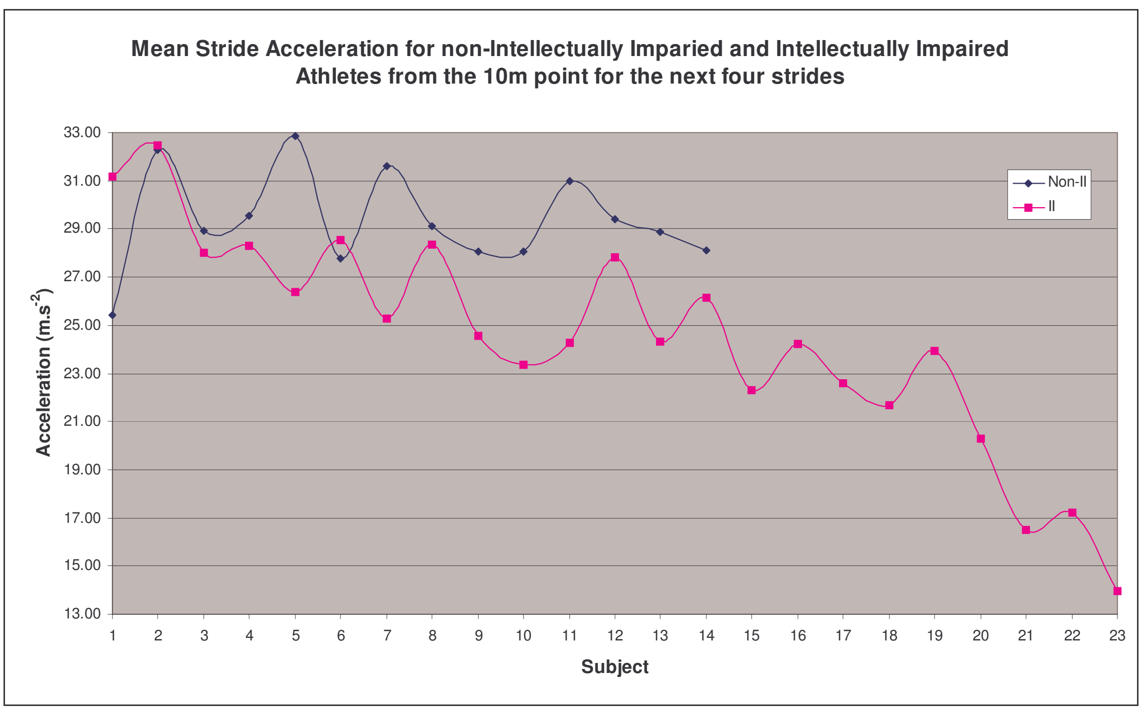

Figure B8

Showing the difference between non-II and II athletes with regard to the mean stride acceleration obtained from the 10m point for the next four strides

Table B9

Difference between non-II and II athletes with regard to the stride frequency from the 10m point for the next four strides

	Stride Frequency	
Subject	**Non-II**	**II**
1	254.24	295.08
2	272.73	320.00
3	263.16	276.92
4	263.16	272.73
5	277.78	268.66
6	263.16	292.68
7	272.73	263.74
8	258.62	285.71
9	263.16	257.14
10	277.78	246.58
11	266.67	253.52
12	263.16	268.66
13	254.24	253.52
14	255.32	276.92
15		243.24
16		272.73
17		257.14
18		243.24
19		264.71
20		246.58
21		225.00
22		225.00
23		214.29

Appendix C

Camera 3 – 20m Data

Table C1

Difference between non-II and II athletes with regard to the overall time taken from the 20m point for the next three strides

	Overall Time	
Subject	**Non-II**	**II**
1	0.46	0.42
2	0.42	0.58
3	0.46	0.43
4	0.44	0.43
5	0.42	0.45
6	0.46	0.42
7	0.42	0.46
8	0.46	0.42
9	0.46	0.48
10	0.42	0.48
11	0.46	0.49
12	0.46	0.44
13	0.44	0.48
14	0.44	0.43
15		0.49
16		0.43
17		0.46
18		0.49
19		0.47
20		0.48
21		0.51
22		0.58
23		0.55

Table C2

Difference between non-II and II athletes with regard to the mean overall time per stride taken from the 20m point for the next three strides

Stride	Non-II Time (Seconds)	II Time (Seconds)	Difference
0	0.00	0.00	0.00
1	0.22	0.24	-0.02
2	0.44	0.48	-0.04
3	0.66	0.80	-0.14

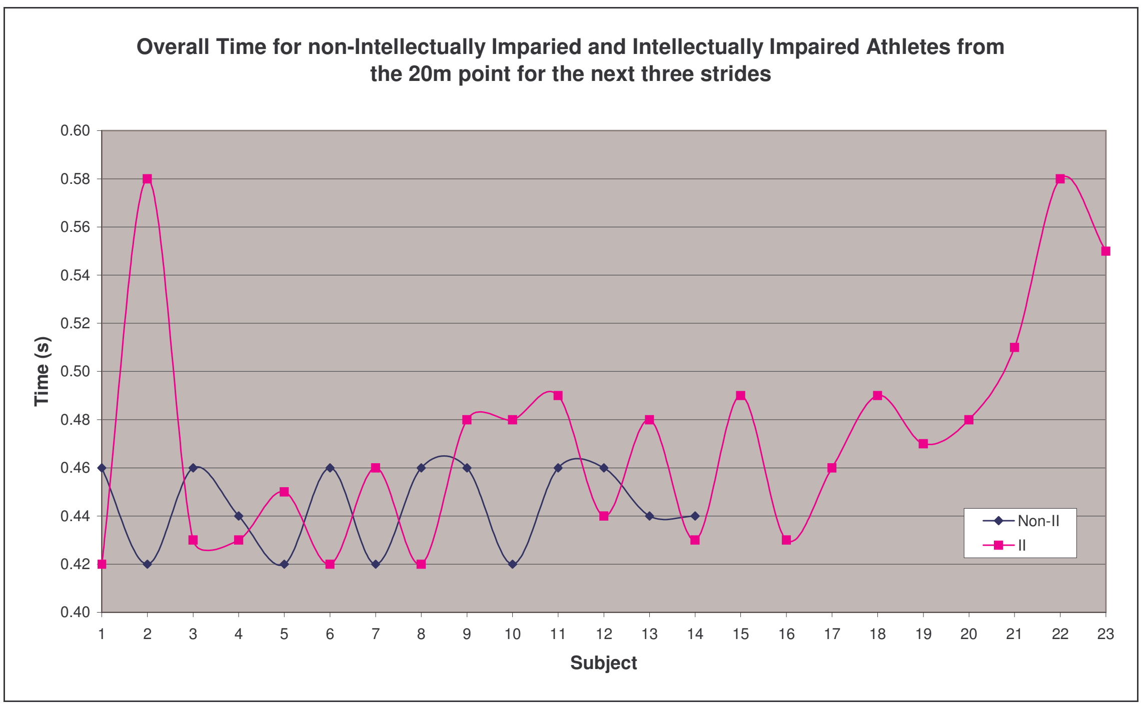

Figure C1

Showing the difference between non-II and II athletes with regard to the overall time taken from the 20m point for the next three strides

Table C3

Difference between non-II and II athletes stride length with regard to the overall distance covered from the 20m point for the next three strides

	Overall Distance	
Subject	**Non-II**	**II**
1	4.13	4.10
2	4.36	5.16
3	4.24	3.92
4	4.15	4.00
5	4.45	3.87
6	4.13	3.65
7	4.28	3.94
8	4.34	3.53
9	4.35	4.01
10	4.45	4.00
11	4.57	3.95
12	4.71	3.92
13	4.35	3.86
14	4.33	3.61
15		3.92
16		3.36
17		3.41
18		3.68
19		3.58
20		3.43
21		3.12
22		3.49
23		2.88

Table C4

Difference between non-II and II athletes with regard to the mean stride length per stride covered from the 20m point for the next three strides

Stride	Non-II Stride Length (Meters)	II Stride Length (Meters)	Difference
0	0.00	0.00	0.00
1	2.12	1.83	0.29
2	2.23	1.86	0.37
3	2.20	1.64	0.56

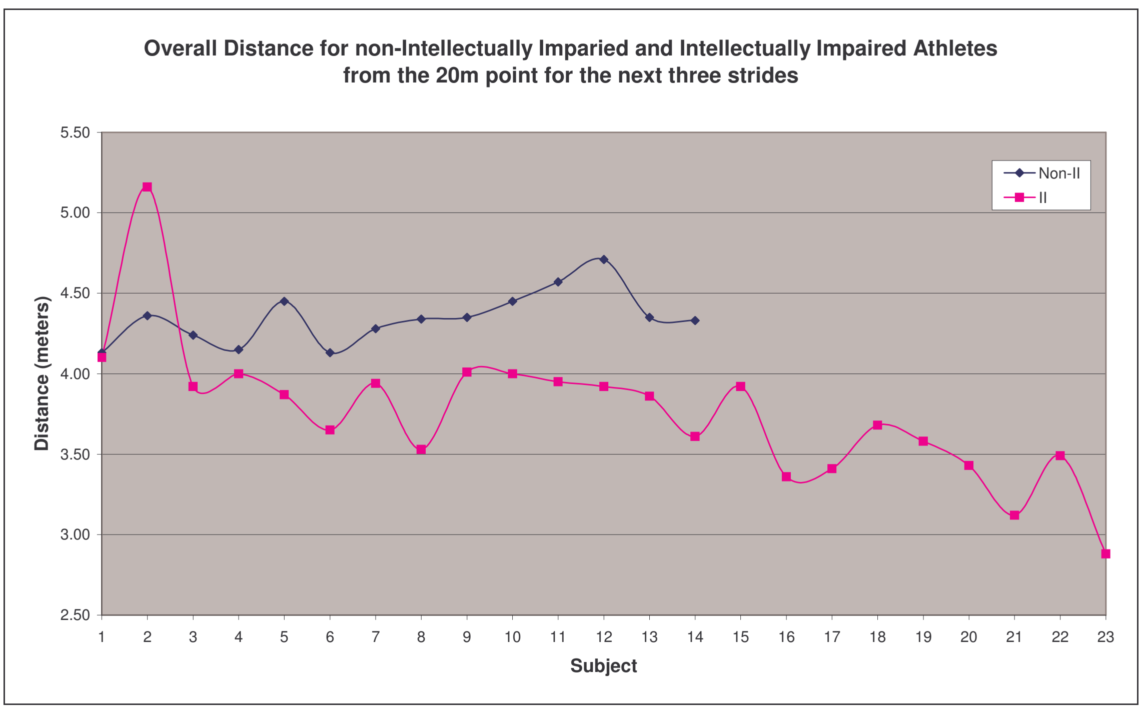

Figure C2

Showing the difference between non-II and II athletes with regard to the overall distance covered from the 20m point for the next three strides

Table C5

Difference between non-II and II athletes stride length with regard to the overall velocity obtained from the 20m point for the next three strides

	Overall Velocity	
Subject	**Non-II**	**II**
1	8.98	9.83
2	10.38	8.84
3	9.22	9.04
4	9.43	9.22
5	10.60	8.67
6	8.98	8.75
7	10.19	8.59
8	9.43	8.46
9	9.46	8.29
10	10.60	8.41
11	9.93	8.03
12	10.24	8.87
13	9.89	8.12
14	9.84	8.40
15		8.03
16		7.90
17		7.73
18		7.48
19		7.66
20		7.21
21		6.13
22		6.06
23		5.19

Table C6

Difference between non-II and II athletes with regard to the mean overall velocity per stride covered from the 20m point for the next three strides

Stride	Non-II Velocity ($m.s^{-1}$)	II Velocity ($m.s^{-1}$)	Difference
0	0.00	0.00	0.00
1	9.78	7.72	2.06
2	9.80	7.80	2.00
3	9.86	6.16	3.70

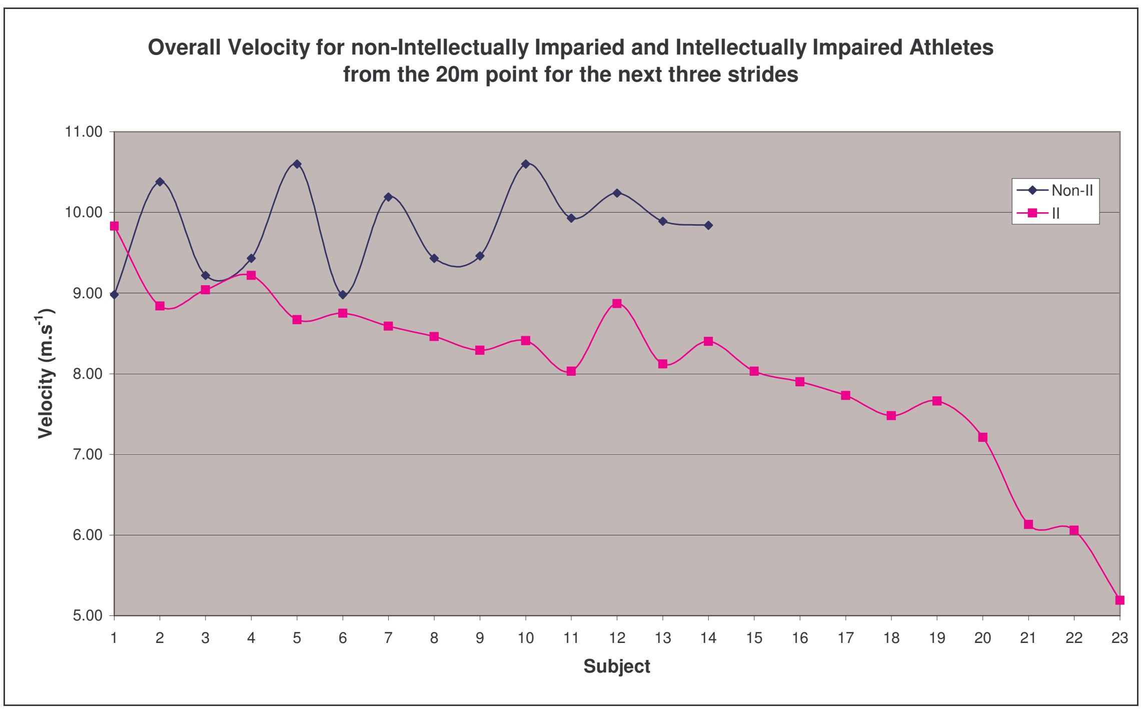

Figure C3

Showing the difference between non-II and II athletes with regard to the overall velocity obtained from the 20m point for the next three strides

Table C7

Difference between non-II and II athletes stride length with regard to the overall acceleration obtained from the 20m point for the next three strides

	Overall Acceleration	
Subject	**Non-II**	**II**
1	19.52	23.57
2	24.72	15.13
3	20.04	20.83
4	21.44	21.26
5	25.23	19.43
6	19.52	20.98
7	24.26	18.72
8	20.51	20.29
9	20.56	17.13
10	25.23	17.69
11	21.60	16.31
12	22.26	20.06
13	22.47	17.07
14	22.37	19.54
15		16.46
16		18.56
17		15.91
18		15.19
19		16.41
20		15.17
21		12.05
22		10.53
23		9.36

Table C8

Difference between non-II and II athletes with regard to the mean overall acceleration per stride covered from the 20m point for the next three strides

Stride	Non-II Acceleration ($m.s^{-2}$)	II Acceleration ($m.s^{-2}$)	Difference
0	0.00	0.00	0.00
1	45.34	32.96	12.38
2	22.12	16.68	5.44
3	14.87	7.93	6.94

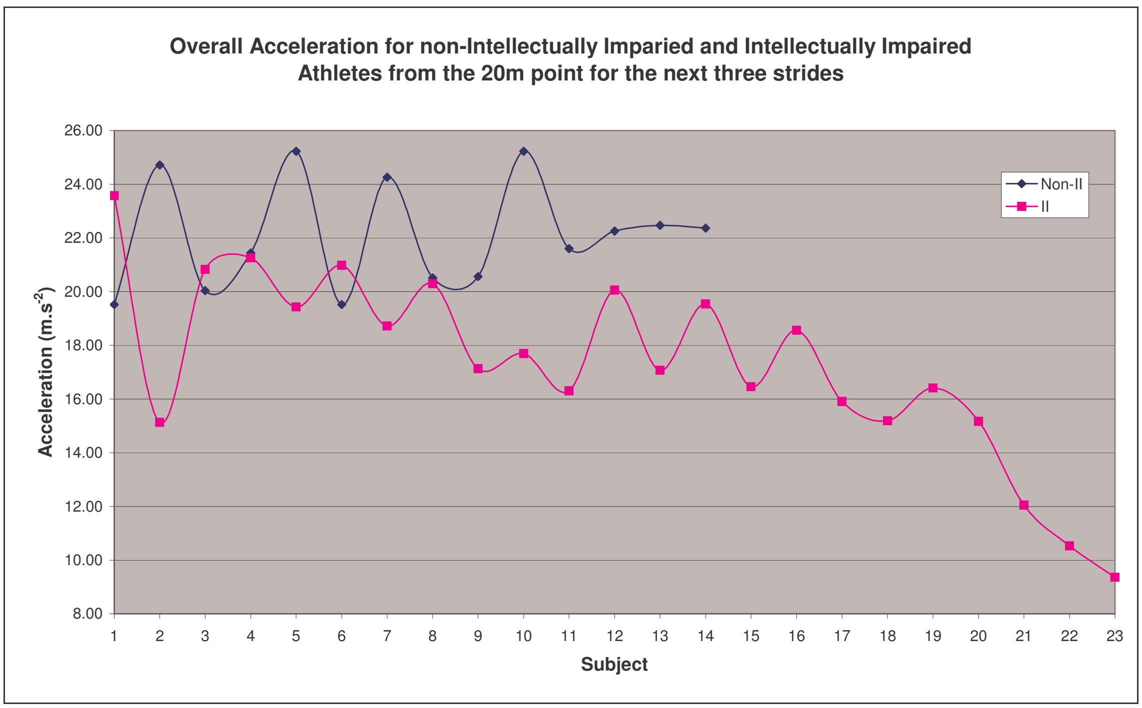

Figure C4

Showing the difference between non-II and II athletes with regard to the overall acceleration obtained from the 20m point for the next three strides

Table C9

Difference between non-II and II athletes with regard to the mean stride time taken from the 20m point for the next three strides

	Mean Stride Time	
Subject	**Non-II**	**II**
1	0.15	0.14
2	0.14	0.13
3	0.15	0.14
4	0.15	0.14
5	0.14	0.15
6	0.15	0.14
7	0.14	0.15
8	0.15	0.14
9	0.15	0.16
10	0.14	0.16
11	0.15	0.16
12	0.15	0.15
13	0.15	0.16
14	0.15	0.14
15		0.16
16		0.14
17		0.15
18		0.16
19		0.16
20		0.16
21		0.17
22		0.19
23		0.18

Table C10

Difference between non-II and II athletes with regard to the stride number and mean stride time per stride covered from the 20m point for the next three strides

Stride	**Non-II Stride Time (Seconds)**	**II Stride Time (Seconds)**	**Difference**
0	0.00	0.00	0.00
1	0.22	0.24	-0.02
2	0.23	0.24	-0.01
3	0.22	0.27	-0.05

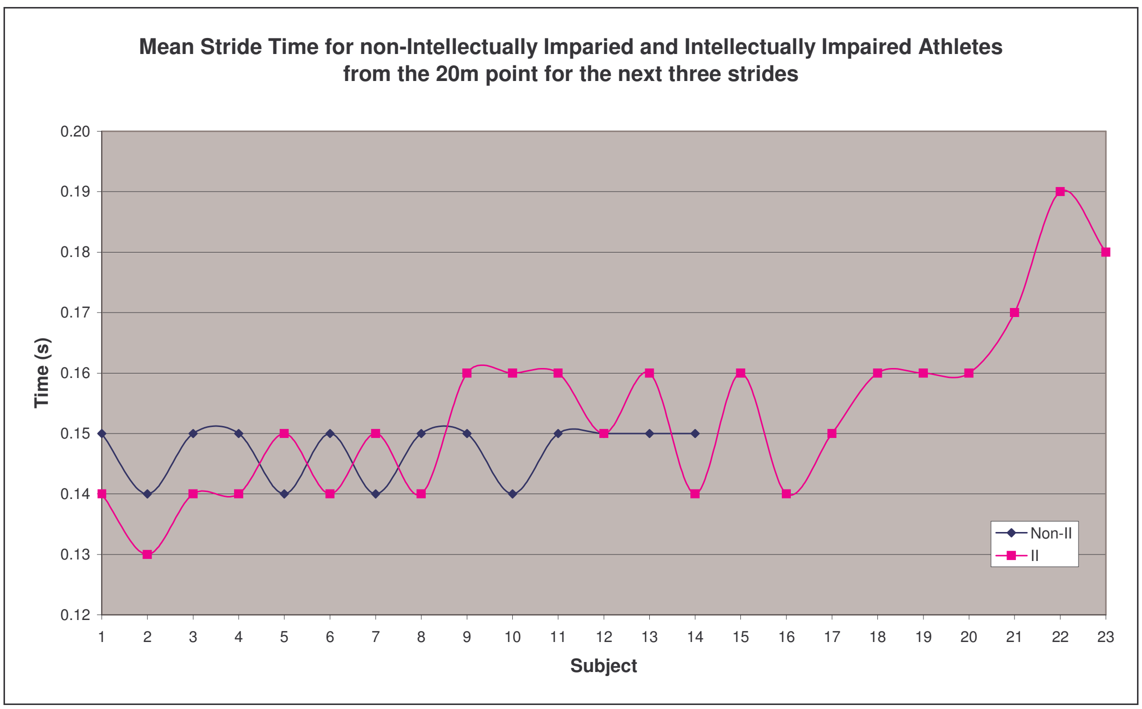

Figure C5

Showing the difference between non-II and II athletes with regard to the mean stride time taken from the 20m point for the next three strides

Table C11

Difference between non-II and II athletes with regard to the mean stride length covered from the 20m point for the next three strides

	Mean Stride Length	
Subject	**Non-II**	**II**
1	1.38	1.37
2	1.45	1.15
3	1.41	1.31
4	1.38	1.33
5	1.48	1.29
6	1.38	1.22
7	1.43	1.31
8	1.45	1.18
9	1.45	1.34
10	1.48	1.33
11	1.52	1.32
12	1.57	1.31
13	1.45	1.29
14	1.44	1.20
15		1.31
16		1.12
17		1.14
18		1.23
19		1.19
20		1.14
21		1.04
22		1.16
23		0.96

Table C12

Difference between non-II and II athletes with regard to the mean stride length per stride covered from the 20m point for the next three strides

Stride	Non-II Stride Length (Meters)	II Stride Length (Meters)	Difference
0	0.00	0.00	0.00
1	2.12	1.83	0.29
2	2.23	1.86	0.37
3	2.20	1.64	0.56

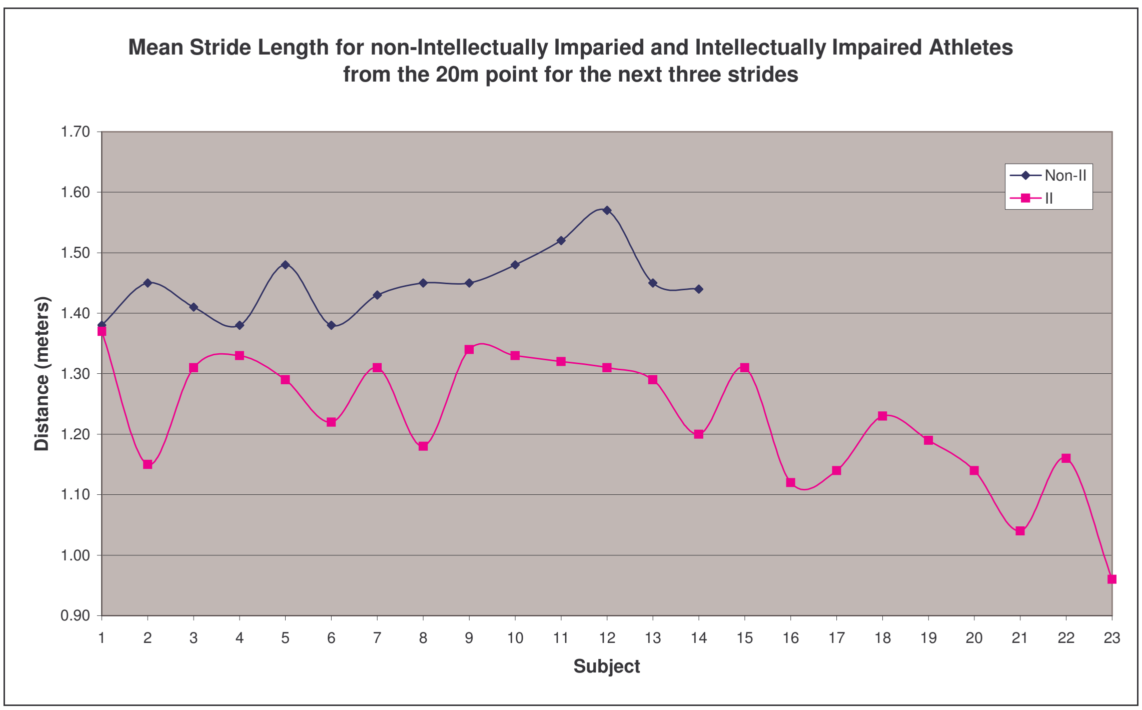

Figure C6

Showing the difference between non-II and II athletes with regard to the mean stride length covered from the 20m point for the next three strides

Table C13

Table showing the difference between non-II and II athletes with regard to the mean stride velocity obtained from the 20m point for the next three strides

	Mean Stride Velocity	
Subject	**Non-II**	**II**
1	5.99	6.57
2	6.92	5.86
3	6.15	6.02
4	6.29	6.15
5	7.07	5.78
6	5.99	5.86
7	6.80	5.74
8	6.30	5.66
9	6.31	5.53
10	7.07	5.62
11	6.64	5.35
12	6.83	5.91
13	6.59	5.41
14	6.56	5.61
15		5.36
16		5.27
17		4.91
18		4.98
19		5.11
20		4.81
21		4.09
22		4.04
23		3.47

Table C14

Difference between non-II and II athletes with regard to the mean stride velocity per stride covered from the 20m point for the next three strides

Stride	Non-II Stride Velocity ($m.s^{-1}$)	II Stride Velocity ($m.s^{-1}$)	Difference
0	0.00	0.00	0.00
1	9.78	7.72	2.06
2	9.83	7.90	1.93
3	10.00	6.03	3.97

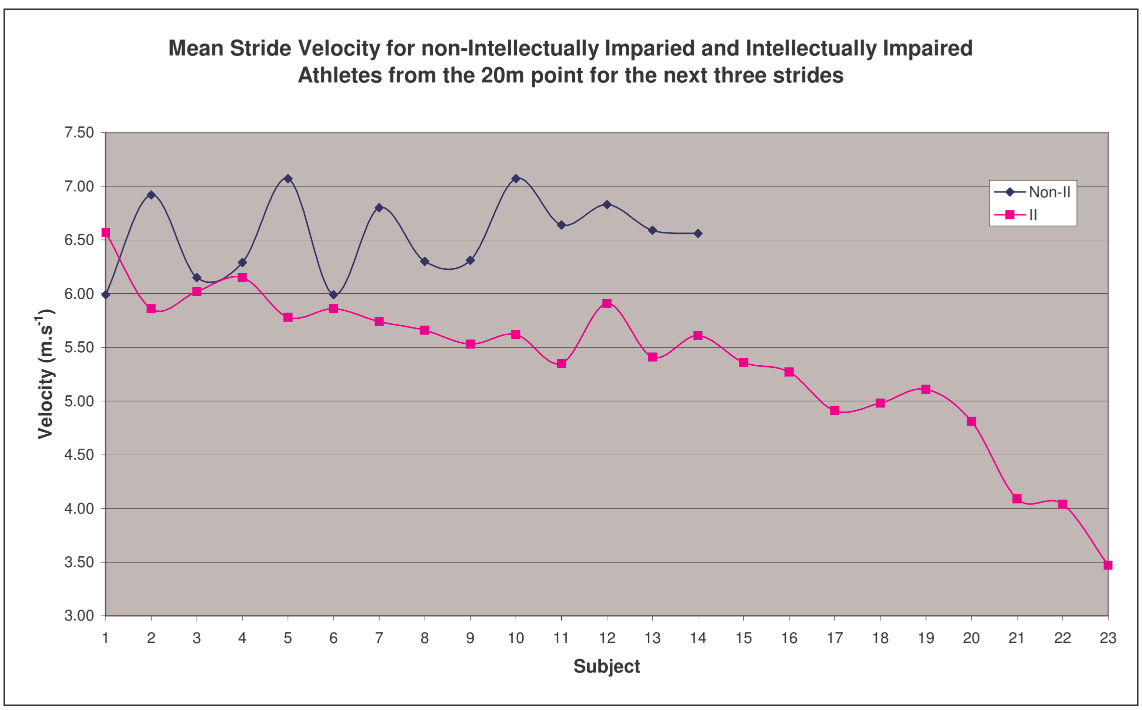

Figure C7

Showing the difference between non-II and II athletes with regard to the mean stride velocity obtained from the 20m point for the next three strides

Table C15

Difference between non-II and II athletes with regard to the mean stride acceleration obtained from the 20m point for the next three strides

	Mean Step Acceleration	
Subject	**Non-II**	**II**
1	26.09	31.59
2	33.06	30.03
3	26.81	27.78
4	28.58	28.35
5	33.77	25.91
6	26.09	28.43
7	32.53	25.16
8	27.50	27.27
9	27.52	22.84
10	33.77	23.73
11	29.00	21.77
12	29.80	26.74
13	29.96	22.77
14	29.82	26.16
15		21.99
16		24.75
17		21.22
18		20.26
19		21.87
20		20.23
21		16.08
22		14.05
23		12.69

Table C16

Difference between non-II and II athletes with regard to the mean stride acceleration per stride covered from the 20m point for the next three strides

Stride	Non-II Step Acceleration ($m.s^{-2}$)	II Step Acceleration ($m.s^{-2}$)	Difference
0	0.00	0.00	0.00
1	45.34	32.96	12.38
2	43.44	33.97	9.47
3	45.56	22.35	23.21

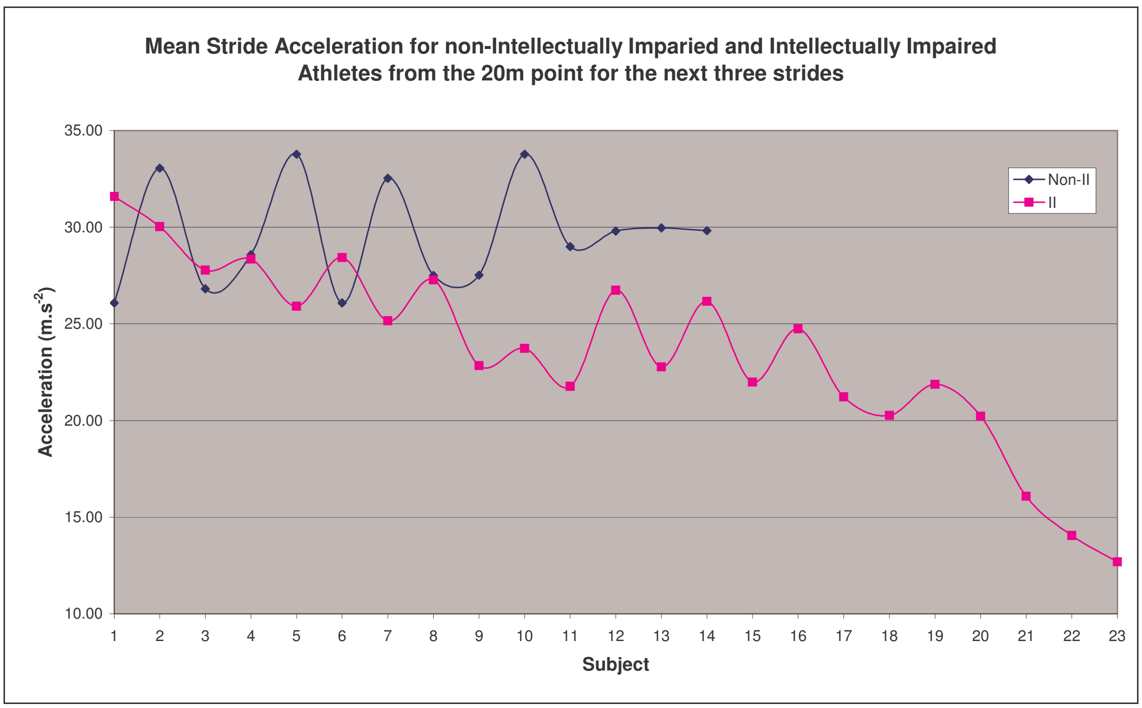

Figure C8

Showing the difference between non-II and II athletes with regard to the mean stride acceleration obtained from the 20m point for the next three strides

Table C17

Difference between non-II and II athletes with regard to the stride frequency from the 20m point for the next three strides

	Stride Frequency	
Subject	**Non-II**	**II**
1	263.16	285.71
2	277.78	310.34
3	263.16	279.07
4	272.73	279.07
5	283.02	266.67
6	263.16	285.71
7	277.78	279.07
8	258.62	285.71
9	267.86	250.00
10	277.78	250.00
11	260.87	244.90
12	260.87	272.73
13	272.73	250.00
14	277.78	179.10
15		244.90
16		279.07
17		260.87
18		244.90
19		255.32
20		246.58
21		230.77
22		210.53
23		216.87