MORPHOLOGICAL VARIABLES AS POSSIBLE RISK FACTORS FOR RUBBER TYRED GANTRY CRANE DRIVERS AT THE PORT OF FELIXSTOWE, UK

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DECLARATION

I, the undersigned, hereby declare that the work contained in this thesis is my own orginal work and that I have not previously in its entirety or in part submitted it at any university for a degree.

Signature: …………………………………… Date:………………………………

SUMMARY

The prevalence of lower back disorders and the high costs involved are an ongoing problem in industrialised countries. Research indicates an estimated 70-80% of all individuals will experience lower back pain (LBP) during the course of their lives (Manek & MacGregor, 2005; Kent & Keating, 2005; Dunn & Croft, 2004; Takeyachi *et al.,* 2003; Carter & Birrel, 2000:6; Nourbakhsh & Arab, 2003; Bernard, 1997:374). It is widely accepted that occupational demands and physical work contribute greatly towards onset, recovery and recurrence of symptoms (Carter & Birrel, 2000:6). Rubber Tyred Gantry (RTG) crane drivers are particularly at risk, as their working posture forces them into various prolonged non-neutral trunk positions (Fehrsen-Du Toit, 2005:24; Rohlmannt *et al.,* 2001; Nachemson, 1963) and extreme trunk flexion (Seider *et al.,* 2003; Hoogendoorn *et al.,* 2000).

Intrinsic factors such as trunk strength (O'Sullivan *et al.,* 2005; Bayramoglu *et al.,* 2001) and trunk stability (Hitt & Lie, 2006; MacDonald *et al.,* 2006; Barker *et al.,* 2006; Hodges *et al.,* 2005; Hodges, 2003; Hodges & Richardson, 1996) as well as anthropometric variables (Franklin *et al.,* 2000:64), can play different roles in incidences of lumbar pain or injury. A job such as RTG crane driving is dependant on a certain amount of strength or physical fitness. A deficit in on or more of these areas can lead to compensation, overload and eventually symptoms and injury. Research has yet to identify factors that predispose certain drivers to injury, and factors determining a quick, safe recovery and return to work.

The purpose of this study was to investigate possible morphological variables as risk factors for RTG crane drivers, for Hutchison Whampoa, at the Port of Felixstowe, UK. The study design was based on a cross sectional, analytical epidemiological study. A sample of 43 RTG drivers completed testing. They were divided into a group of drivers who had never had lower back pain or symptoms (n=22), and a group of drivers who had had a previous history of lower back pain (n=21). All subjects were asymptomatic at the time of testing. Although not significant ($p > 0.05$), the results of the study showed that average performance deficit (the power needed to maintain or repetitively produce a force) tended to be higher in those subjects without a previous history of pain. The flexion/extension ratio also tended to be better for this group. The subjects without a past history of lower back pain were, surprisingly, found to be older than the other group. This explains the higher body weight, waist-to-hip-circumference, body mass index, and fat percentage for this group, as these measurements all tend to increase with age. It also explains the lower peak torque to body weight values for that group, as peak torque would decrease with increased body weight.

This is the first study to look at morphological variables and isokinetic testing of RTG crane drivers, and the relationship between these variables and lower back pain.

Key words: Crane drivers; Morphological variables; isokinetic testing; lower back pain

OPSOMMING

Die hoë koste verbonde aan, asook die hoeveelheid voortdurende lae-rug beserings in industriële lande, is ‘n aaneenlopende probleem. Navorsing toon dat 70-80% van alle individue laer-rugpyn sal ervaar deur die loop van hul lewens (Manek & MacGregor, 2005; Kent & Keating, 2005; Dunn & Croft, 2004; Takeyachi *et al.*, 2003; Carter & Birrel, 2000:6; Nourbakhsh & Arab, 2003; Bernard, 1997:374). Dit is aanvaar dat werksvereistes en fisiese werk grootliks bydra tot die oorsaak, herstel en herhaling van simptome (Carter & Birrel, 2000:6). RTG hyskraan bestuurders is veral individue wat ‘n groter risiko toon ten opsigte van laer-rug beserings weens werkspostuur wat hul noodsaak om verskeie langdurige nie-neutrale mid-rug posisies (Fehrsen-Du Toit, 2005:24; Rohlmannt *et al.*, 2001; Nachemson, 1963), asook ekstreme mid-rug fleksie handhaaf (Seider *et al.*, 2003; Hoogendoorn *et al.*, 2000).

Sekere individuele intrinsieke faktore soos mid-rug krag (O'Sullivan *et al.*, 2005; Bayramoglu *et al.*, 2001) mid-rug stabiliteit (Hitt & Lie, 2006; MacDonald *et al.*, 2006; Barker *et al.*, 2006; Hodges *et al.*, 2005; Hodges, 2003; Hodges & Richardson, 1996), en antrpometriese veranderlikes (Franklin *et al.*, 2000:64), kan ‘n aansienlike verhoging in moontlike laer-rug pyn of –beserings meebring. ‘n Werk soos RTG hyskraan bestuur is afhanklik van sekere hoeveelheid krag of fisiese fiksheid. ‘n Tekortkoming in enige van hierdie areas kan lei tot oorkompensering, oorbelading en uiteindelike simptome van besering. Vrae wat navorsing nog moet antwoord is onder andere die faktore wat aanleiding gee tot beserings asook wat vinnige en veilige terugkeer na werk vir bestuurders bepaal.

Die doel van die studie was om moontlike morfologiese veranderlikes en risiko faktore te bestudeer vir RTG hyskraan bestuurders, vir Hutcinson Whampoa, te Felixstowe hawe, VK. Die rol wat hierdie faktore speel in die oorsaak en ontwikkeling van rugpyn word ook ondersoek. ‘n Protokol van toetse is gekies om moontlike morfologiese risiko faktore

uit te lig en daardeur bestuurders wat meer geneig is om laer-rugpyn te ontwikkel te identifiseer.

‘n Totaal van 43 RTG bestuurders het die toets voltooi. Hierdie bestuurders is verdeel in ‘n groep wat nog nooit laer-rugpyn of simptome getoon het nie (n=22) en ‘n groep bestuuders wat wel vorige geskiedenis van laer-rugpyn het (n=21). Alle deelnemers was asimptomaties met die aanvang van die toetsing. Alhoewel resultate van die toets nie noemenswaardig was nie ($p>0.05$), het dit wel getoon dat algemene prestasie tekortkoming (spierkrag benodig om kraguitset te handhaaf of om herhaaldelik uit te voer) geneig was om hoër te wees in individue sonder ‘n vorige geskiedenis van rug besering. Die fleksie/ekstensie verhouding het ook beter vertoon in hierdie groep. Individue sonder vorige geskiedenis van laer-rugpyn is interessant genoeg, ouer as die met geskiedenis van laer-rug beserings. Dit verduidelik die hoër liggaamsgewig, middel-heup-verhouding en liggaamsmassa indeks en vet persentasie van hierdie groep weens die feit dat al reedsgenoemde geneig is om met ouderdom toe te neem. Dit kan ook piek-kraguitset tot liggaamsmassa waardes van hierdie groep verduidelik omdat piek-kraguitset sal verminder met toename in liggaamsmassa.

Hierdie is die eerste studie wat die uitkyk bied op morfologiese veranderlikes tesame met isokinetiese toetsing van RTG hyskraan bestuurders en die verhouding tussen hierdie veranderlikes en laer-rugpyn.

Sleutelwoorde: Hyskraan bestuurders; Morfologiese veranderlikes; Isokinetiese toetsing; Laer-rugpyn.

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ABBREVIATIONS

ACSM	American College of Sports Medicine
APD	Average Performance Deficit
APR	Average Performance Ratio
AP	Average Power
ASIS	Anterior Superior Iliac Spine
AZ	Anatomical Zero
BF%	Body Fat Percentage
BMI	Body Mass Index
BP	Back Pain
BW	Body Weight
CCD	CCD Design and Ergonomics Ltd
CD	Critical Difference
CLBP	Chronic Low Back Pain
CT	Computed tomography
CTD	Cumulative Trauma Disorder
CV	Coefficient of Variance
ER	Endurance Ratio
FCE	Functional Capacity Evaluation
FER	Flexion Extension Ratio
GET	Gravity Effect Torque
GNP	Gross National Product
HIV	Human Immunodeficiency Virus
IASP	International Association for the Study of Pain
ICC	Intraclass correlation coefficient
IPRS	Injury Prevention and Rehabilitation Services
ISAK	International Society for the Advancement of Kinanthropometry
LBP	Low Back Pain
MRI	Magnetic Resonance Imaging

MSD	Musculoskeletal Disorders
MVIC	Maximal Voluntary Isometric Contraction
NHS	National Health Services
NIOSH	National institute for Occupational Safety and Health
POF	Port of Felixstowe
PT/BW	Peak Torque to Body Weight
PT	Peak Torque
ROM	Range of Motion
RSI	Repetitive Strain Injury
RTG	Rubber Tyred Gantry
RTW	Return to Work
SEM	Standard error of the measurement
SF-12	Short Form 12
SF-36	Short Form 36
SIJ	Sacroiliac Joint
SI	Sacroiliac
SLR	Straight Leg Raise
TrA	Transverse Abdominus
TST	Trunk Stability Test
TW	Total Work
UK	United Kingdom
US	United States
VK	Verenigde Koninkryk
WBV	Whole Body Vibration
WCB	Worker's Compensation Board
WHR	Waist to Hip Ratio
YMCA	Young Mans Christian Asssociation
ZSP	Zero Starting Position

CHAPTER ONE

STATEMENT OF THE PROBLEM

BACKGROUND

Lower back pain (LBP), as a chronic, non-specific condition, is a common and costly problem (Feuerstein *et al.,* 2004). It is one of the most common complaints in primary health care, and the incidences appear to be on the increase. Epidemiological studies of LBP, both work related and non-work related, indicate a significant rise in the prevalence of back pain, as well as its associated costs in both the United States (Feuerstein *et al.,* 2004), and the United Kingdom (UK). It is said to be one of the fastest growing reasons for work loss and health care visits (Ferguson *et al.*, 1996).

An estimated 70% to 80% of individuals will experience LBP during the course of their lives (Manek & MacGregor, 2005; Kent & Keating, 2005; Dunn & Croft, 2004; Takeyachi *et al.*, 2003; Carter & Birrel, 2000:6; Nourbakhsh & Arab, 2003; Kaplansky, 2000:107; Bernard, 1997:374), of which 80% will report recurrent episodes. An estimated 5-15% of these patients will develop chronic low back pain (CLBP) (Liddle *et al.,* 2005; Fransen *et al.,* 2002). Studies for the western industrialized population show similar results (Takeyachi *et al.,* 2003; Torstensen *et al.,* 1998).

LBP is affected and caused by various psychosocial (Moshe & Levin, 2005; Van Nieuwenhyse *et al.,* 2004), occupational, physical and unidentified factors. It is widely accepted that occupational demands and physical work contribute greatly towards onset, recovery and recurrence of symptoms (Carter & Birrel, 2000:6). Occupational factors such as heavy physical loading, prolonged sitting, sustained non-neutral work postures and vehicular driving have been associated as risk factors for LBP, and spinal degeneration (Carter & Birrel, 2000:6; Rohlmannt *et al.,* 2001; Videman & Battie, 1999; Smedley *et al.,* 1995; Bernard, 1997:374; Nachemson, 1963). Associations have been drawn between extreme or prolonged forward flexion and disc herniation (Seidler *et al.*, 2003). In a study by Hoogendoorn *et al.*, (2000), extreme trunk flexion was found to be a risk factor in LBP particularly when the trunk is in a minimum of 60 degrees of flexion for more than 5% of the working time.

Trunk muscle strength has also been indicated as a risk factor for LBP (O' Sullivan *et al.,*2005; Bayramoglu *et al.,* 2001). Various methods have been practised to assess trunk muscle strength, although few have been indicated as objective and quantitative. Isokinetic testing, however, has been found to be valid and reliable method of testing muscle strength and function (Karatas *et al.,* 2002; Delitto *et al.,* 1991; McLean & Conner, 1994), which is reproducible (McLean & Conner, 1994). Isokinetic testing in a semi-standing position, as a quantitative measure of trunk muscle strength, has been found to be safe and effective (Langrana & Lee, 1984).

Previous studies in back testing have used peak torque as a measure of muscle strength (Knapnik *et al.,* 1983; Langrana *et al.,* 1984; Bayramoglu *et al.,* 2001), although it is widely accepted that testing can vary with regard to gender and body weight (Kannus, 1994; Newton & Waddell, 1993). Thus, mean peak torque to body weight values (PT/BW) have been used for normative data, and no gain in accuracy, reliability and validity was found between various speeds (Brown, 2000: 265-266). Although average performance deficit (APD) has been found to be a reliable measurement in trunk testing (Brown, 2000: 264), it does require a testing protocol of 5 different speeds. Peak torque in relation to body weight is another practical way to test trunk muscle strength that is time efficient and accurate.

Isometric tests have also been found to produce valid and reliable data on muscle strength in a certain range of movement (Graves *et al.,* 1990). Correlations between Isokinetic, Isometric and Isotonic measurements have been found to be high, indicating that they are all measuring maximal voluntary strength (Knapik *et al.,* 1983).

Spinal stability and its relevance for rehabilitation and management of LBP, has become increasingly popular in recent years (Hitt & Lie, 2006; Hodges *et al.,* 2005). Assessment of lumbo-pelvic mechanics has been indicated for prevention, pre-screening and evaluation (Vezina & Hubley-Kozey, 2000; Richardson *et al.,* 1999; Mitchell *et al.,* 2003).

Anthropometric variables also play a major role in injury onset and recovery (Beckham & Earnest, 2003; Franklin *et al.,* 2000: 63; Martin *et al.,* 2003). Various factors such as Body Mass Index (BMI), Waist to hip ratio (WHR), Body fat percentage (BF%) and flexibility can not only affect performance in strength measures but can also increase the risk of developing a low back condition.

LBP is a risk factor for Rubber Tyred Gantry (RTG) crane drivers due to their working postural position, with an unfavourable flexed position that can lead to neck and back problems. The viewing demands dictate the crane driver’s working posture. A long period of time is spent looking downwards, and the driver’s working posture can, therefore, involve slight to extreme back and neck flexion for prolonged periods of time, making them vulnerable to neck and back pain. Frequent bending and whole body vibration are proven risk factors in back conditions (Burdorf, 1997; Bernard, 1997: 375). Burdorf and Zondervan (1990) found an elevated occurrence of LBP in crane drivers, compared to non-crane drivers, as they were exposed to prolonged, awkward, sedentary postures.

LBP incidences in this particular RTG population have been steadily on the increase in the last few years, despite innovations in health and safety and ergonomics. LBP accounted for 1908 days lost in absence for the Port of Felixstowe (POF) in 2003, which was 56% of total absence. This accounts for massive losses in production and sickness pay, not to mention concerns of staff turnover and compensation claims.

LBP and associated work absence is affected by various factors, but the physical and anthropometric variables are easiest to quantify and therefore correct and manage. The physical and anthropometric factors can be curbed through effective prevention, correct diagnosis, treatment and management. Companies are continuing to seek new ways of reducing injury and associated loss. The most effective way of doing this is through management of musculoskeletal injuries, as well as identifying causal and risk factors. The Second International Forum for Primary Care Research in LBP (Borkan *et al.*, 1998) listed predictors and risk factors for CLBP as a priority in research.

Management of acute LBP is also essential in preventing the injury from developing into a more chronic condition, and therefore possibly a more long term absence. If determining risk factors and implementing prevention strategies can decrease absenteeism, by even a small percentage, it can save companies thousands of pounds. An understanding of risk factors involved could aid in correct rehabilitation that could help to manage an acute condition, and enable workers to quickly and safely, return to work.

AIM OF THE STUDY

1. Research Question

This study proposes an investigation regarding morphological variables as possible risk factors for RTG crane drivers, at the POF, UK.

The aim was to investigate the relationship between these morphological variables and the ergonomics of the RTG driver's working posture; and the role that these different factors play in the predisposition and development of LBP.

Studies have indicated that RTG crane driving can increase the risk for LBP, due to a variety of occupational reasons. Research has yet to answer questions as to what predisposes certain drivers to injury, and what determines a quick, safe recovery and return to work.

The aim of this study was to investigate muscle strength and stability, anthropometric data, and a range of other factors, with regard to the role that these factors play in the development of LBP. A protocol of tests was chosen to highlight possible morphological risk factors that could identify those drivers who are more likely to develop low back symptoms.

This data could possibly be useful to use in occupational pre-screening of RTG drivers to reduce the risk of spinal related conditions, and aid in specific rehabilitation. The long term expected outcome for gathering this information would be to decrease work related injuries, and improve sickness absence statistics associated with LBP.

2. Targeted Outcome

To reduce the occurrence of musculoskeletal injuries by identifying weakness or imbalance in the spinal flexors and extensors, stabilizers and other relevant muscle groups. To consider possible morphological factors that could subject this population group to physical risk factors within their environment. This will have a positive effect on the number of employees completing successful and relevant training and therefore reduce time and money spent on unsuccessful training. Through pre-screening and early identification of these risk factors, work loss and absenteeism can be prevented or minimized, and safe return to work programs can be implemented.

LIMITATIONS

During this study the main limitations were expressed as follows:

1. Although 108 questionnaires were returned, only 42 drivers completed the full battery of tests. The drivers had to complete the protocol in their own time, and due to the lengthy nature of the tests, the compliance by the drivers was poor.
2. There was a lack of relevant literature on testing RTG drivers, and therefore a battery of tests was set up looking at the physical and functional demands of the duties as RTG crane drivers, and this specific test protocol had not been used in the past.

Although this study aims to highlight morphological variables that could be possible risk factors for RTG drivers, further investigations into development of norms will need to be done in the future. This will need to test a large number of drivers to develop norms for accurate comparisons and pre-screening.

This study could open the doors to further research with regard to long-term effects of pre-screening, and work absence due to morphological screening process. It would be useful to extend this study to other ports, or areas and companies using RTG crane drivers, as this study is specific to the POF's employees and the cranes that operational there. It could have financial implications for companies that seek to provide employees with specific and relevant rehabilitation, and decrease sickness absence and work loss.

CHAPTER TWO

LITERATURE REVIEW

BACKGROUND

Lower back pain (LBP), as a chronic, non-specific condition, is a common and costly problem that puts great demands on the health system (Feuerstein *et al.,* 2004; Kaplansky, 2000:2). It is one of the most common complaints in primary health care, and the incidences appear to be on the increase. Epidemiological studies of LBP, both work related and non-work related, indicate an annual increase of 5% and a prevalence of 15% to 20% in the United States (Feuerstein *et al.,* 2004), with Britain steadily reaching similar statistics. It is said to be one of the fastest growing reasons for work loss and health care visits (Anderson, 1999; Ferguson *et al.,* 1996).

An estimated 70% to 80% of individuals will experience LBP during the course of their lives (Manek & MacGregor, 2005; Kent & Keating, 2005; Dunn & Croft, 2004; Takeyachi *et al.,* 2003; Carter & Birrel, 2000:6; Nourbakhsh & Arab, 2003; Kaplansky, 2000:107; Bernard, 1997:374), of which 80% will report recurrent episodes, and 5-15% of such patients will develop CLBP (Liddle *et al.,* 2005; Fransen *et al.,* 2002).

1. Definition

Understanding the concept of LBP is complicated by the definition of LBP, and how it should be measured. The factors affecting the concept of pain must be considered, as well as defining the exact anatomical position of "LBP".

The International Association for the Study of Pain (IASP), defined pain as "an unpleasant sensory and emotional experience associated with actual or potential tissue damage, or described in terms of such damage" (Merskey *et al.,* 1979). Pain is therefore considered as a psychological and physical experience, and this definition is widely accepted for research and clinical purposes.

Back pain can be identified, anatomically, as pain between the C1 and S1 region, while LBP is pain limited to the region of L1 and S1.
It is important to place back pain in a well defined population in which the pain is severe enough to cause clinically meaningful decrement to the patient's functional activity, which lasted for some minimum length of time. Defining significance and severity of pain is difficult, but a clear distinction must be drawn between chronic and acute pain.

Chronic low back pain (CLBP) can be defined as pain lasting more than twelve weeks, or recurring as multiple episodes over a year (Feuerstein *et al.,* 2004). The risk of developing CLBP has been reported to be high (Fransen *et al.,* 2002), as 85% of back pain sufferers are classified as having non-specific CLBP (Liddle *et al.,* 2005). Approximately 10-20% of LBP sufferers will develop chronic condition (Maher, 2004; Liddle *et al.,* 2005; Fransen *et al.,* 2002). CLBP poses a health problem in western countries, where 38% of British adults reported a significant episode of LBP in one year. It does not necessarily indicate ongoing tissue damage, but rather this is subjective to the patient's perception of physical impairment and pain (Liddle *et al.,* 2005).

Acute pain is pain that can be well defined, and localised, with a clear etiology. It is expected to last either 0-4 weeks, or in the case of sub-acute pain, 4-12 weeks. Healing of such acute pain usually involves resting of the injured part (White & Andersson, 1991).

LBP is associated, and linked to many factors such as age, body type, sex, stress, smoking, physical activity, occupation and pervious history (Roncarati & McMullen, 1988). These factors, combined with psychosocial and physical factors, can widely affect a person's perception of pain, as well as how well they recover, or return to full function (Campello *et al.,* 2006).

EPIDEMIOLOGY OF LOW BACK PAIN

Most epidemiological studies of LBP have been done in North America, the UK and Scandinavian countries. It was found to be a common problem, with estimates of the yearly incidence ranging from 1.4% - 4.9%, point prevalence ranging from around 10% to over 50% (see Table 2), and lifetime prevalence from about 14% to well over 70% (Giles & Singer, 1997:4). The prevalence of disabilitating back pain in Britain, for which benefits are paid, has risen exponentially in the past 20 years. Back pain is also a major cause of chronic disability in the United States (US). In 1987, and estimated 6.5 million American adults had health care visits related to non-specific back pain. This figure increased to 7.4 million (a 13.8% increase) in 1997, an estimated 2% of the American gross national product each year (Cats-Baril & Frymoyer, 1991). Studies indicate that 60% to 80% of the population in the western industrialised world will experience LBP at some stage in their lives (Torstensen *et al.,* 1998; Carter & Birrel, 2000:6; Nourbakhsh & Arab, 2003; Takeyachi *et al.,* 2003). The Australian 2001 National Health Survey reported that 21% of Australians suffered from long-term back problems. It also remains one of the most difficult and costly medical problems in the industrialised world (Curtis *et al.,* 1994; Takeyachi *et al.,* 2003). Although 90% of back pain sufferers will spontaneously recover, up to 20% will seek health care, and a further 10% will seek some kind of compensation (Millender *et al.,* 1996). Table 1 shows the increasing prevalence of back pain in the working population.

The occurrence of LBP is as common in South Africa, with 74% of adult women in an informal settlement reporting complaints of LBP (Tshabangu & Coopoo, 2001).

Table 1: Prevalence of back pain in the general population and workers (Millender *et al.*, 1996)

YEAR	POPULATION	CONDITION	PREVELENCE %
1984	US workers	Back pain	14-16
1986	UK workers	Back pain	20
1986	US workers	Back pain for at least 2 weeks	10
1987	Denmark workers	LBP	8
1989	US workers	Back/Spine trouble	20
1995	US workers	Back pain > 1 week	18
1995	UK workers	LBP within the last month	35-37

Table 2: Age- and sex- specific prevalence rates of LBP (Kaplansky, 2000:233)

Frequency in Age Groups								
Men (age)	20	25	35	45	55	65	75	All
Lifetime Prevalence	51.7	50.6	53.8	53	53.8	41.8	32.6	51.3
Point Prevalence	22.2	19.5	20.7	23.5	23	26.6	17	15.2
Women (age)	20	25	35	45	55	65	75	All
Lifetime Prevalence	46	56.1	61.1	64.9	60	52.7	46.4	57.8
Point Prevalence	30.2	23.6	26	31.4	32.6	34.4	33.4	28.4

1. Economic Cost

CLBP is a major health problem with enormous economic and social costs. LBP in general is said to be the main cause of absenteeism and disability in industrialised societies. Compensation claim costs, disability, and production losses run into billions of dollars and pounds. LBP is an international problem, affecting most Western countries and is classified as a major public health problem.

1.1 Occupational Low Back Pain

The high cost and prevalence of musculoskeletal disorders in industrialised countries is an ongoing problem. During the course of their careers, up to 85% of workers will miss work or seek professional care for musculoskeletal pain (Proctor *et al.,* 2004). Although most of these workers will recover quickly, there is a small portion that will develop a more long-term, chronic problem or disability.
Occupational LBP remains the dominant musculoskeletal disorder affecting the working population, representing 25-40% of workers' compensation claims (Kent & Keating, 2005; Kaplansky, 2000:233; Hadler, 1993:173), accounting for more than half of the musculoskeletal problems (Taimela *et al.,* 2000), and second only to respiratory conditions as a major cause of work loss. The chronic disabilitating work-related musculoskeletal disorders account for disproportionably large percentages of total costs associated with pain. Chronic back pain develops in only 10% of workers, and yet accounts for 80% of the costs arising from chronic cases (Proctor *et al.,* 2004). CLBP sufferers are in the minority of those with back pain, yet they account for most of the costs associated with repeated treatment, absence from work, disability and early retirement. It is estimated that approximately 30-40% of all worker's compensation board (WCB) claims concern back injuries (Bishop & Wing, 2003; Krause *et al.,* 1998). Compensable back pain has escalated in the industrial world, and costs to companies are on the increase as more and more employees claim liability (Pai & Sundaram, 2004; Hadler, 1993: 173)

In the United States, disorders of the spine is one of the largest public health problems, causing injury to approximately 2.5 million, disabilitating approximately 4.8 million adult Americans (Kaplansky, 2000:233) and permanently disabilitating 2.6 million people (Frymoyer & Cats-Baril, 1991). The annual cost related to back pain ranges from $20-$50 billion (Pai & Sundaram, 2004). LBP is one of the most frequent factors for decrease in work capacity, and absenteeism. It causes an average loss of 28.6 days per 100 workers each year (Kaplansky, 2000:233; King, 1993). Chronic pain in the US accounts for 700 million lost work days, and $65 billion in health care costs, compensation, and litigation, with LBP making up $14 billion of those costs (Tollison & Kriegel, 1989:260). Back care, in the past, has amounted to 60% of the $50 billion worker's compensation costs (King, 1993).

General practitioner visits for back pain in the UK ranges from 7%-9.8% (Watson & Main, 2004). Although back disability is less prevalent in the UK, than in the US, it still affects 25% of all working men, and disabling 79 000 persons in 1979 alone. One third of the musculoskeletal problems are back related, causing absenteeism from work for 2.1% of the population. That is, 1.1% for women and 2.26 % for men (Kaplansky, 2000:234). The few CLBP sufferers cost the National Health Services (NHS) £265- 383 million. The estimated indirect cost brings the total to over £10000 million.

In Norway, absenteeism from LBP made up 22% of all medical certificates issued by physicians, and an estimated 36 000 employees have retired due to the problem.
Retirement from a chronic low back condition is 12 500 per annum, and 25% of all new pension funds, in Scandinavia. Absenteeism from LBP occurs in 10.9% of workers, with 9.9% of those being disabled for longer than 6 months. Every 10 per 100 men, and 6 per 100 women are absent annually from LBP (Kaplansky, 2000:234). In the Netherlands, 1.5% of the Gross National Product (GNP) cost was as a result of back pain, and only 3% of that was used for treatment purposes (Van Tulder *et al.*, 1997). Swedish low back sufferers cause 7 526 sickness absence episodes in one year (Kaplansky, 2000:233).

1.2 Total Cost

It is difficult to accurately quantify the total cost of LBP. Frymoyer & Cats-Baril (1991) divided the total cost into direct and indirect costs, and estimated the cost in 1990, from a study done in 1984 (see Table 1.3).

Direct costs relate to goods and services for the delivery of medical care, including hospital, physician, and other treatment costs. Direct costs can also include insurance, social security benefits, disability and death benefits (Kaplansky, 2000:234; Frymoyer

& Cats-Baril, 1991).

Indirect costs reflect an estimation of work loss and transfer payments (Frymoyer & Cats-Baril, 1991). They can also include production losses, personal losses and administrative costs associated with new hiring, legal expenses, training and supervision (Kaplansky, 2000:233).

Direct cost

For outpatient diagnostic and therapeutic services costs, the increased use of imaging technology, such as Computed tomography (CT) and Magnetic Resonance Imaging (MRI) scans, have caused great inflation. Other direct costs include hospital costs, outpatient and emergency room services, and physician visits. An estimated 16 million physician visits were for lumbar strains alone, which is increasing continuously due to population growth and increased use of services. Visits to Chiropractors, Physiotherapists and Occupational Therapists are also on the increase. Added to these costs are the 4.3 million visits to Psychiatrists and Neurologists, per annum. Nursing services, drugs and administration were also added to the direct costs. For non-health sector goods and services, low back disability litigation in the state of California alone was $600 million, which could be estimated at $5 billion nationwide (Frymoyer & Cats-Baril, 1991).

Indirect costs

Indirect costs consist of worker' lost earnings, and homemaker's potential lost earnings, and was calculated to be $3.6 billion for 1990 (Frymoyer & Cats-Baril, 1991), and an estimated £10668 million for the UK in 1998 (Maniadakis & Gray, 2000). Indirect costs remain problematic to estimate, and could often be inflated to a much more enormous cost in worker's compensation.

These associated costs make effective rehabilitation and prevention of injuries even more important to companies and industries. It is suffice to say that the costs are extremely high and solutions need to be sought in order to curb the economic burden that can be crippling to some industries.

Table 3: The estimated direct costs for back pain in the US in 1990 (Frymoyer & Cats-Baril, 1991), 1998 (Luo *et al.*, 2003) and for the UK in 1998 (Maniadakis & Gray, 2000).

Direct costs	**US$ (1990)**	**US$ (1998)**	**UK% (1998)**
Hospital Inpatient	6 780 462 000		14%
Outpatient and Emergency room	387 980 000		
Outpatient diagnostic and therapeutic	2 000 000 000		5%
Physician inpatient	1 707 080 000		31% (hospital sector in general)
Physician office outpatient & emergency room	2 411 690 000		
Other practitioners	3 825 119 000		37%
Drugs	191 697 000		7%
Nursing homes	4 952 394 000		6%
Prepayment	615 080 000		
Non-health sector goods & services	1 564 651 000		
Total Direct Costs	**24 436 153 000**	**90.7 billion**	**£1632 million**

1.3 Crane Drivers

LBP is a problem in most companies, and especially in those involving heavy physical jobs. The POF is no exception, and has revealed the following statistics on absenteeism due to LBP.

It is clear to see that the POF is following the trends of the industrialised world. For Quayside Gantry drivers, the amount of days lost due to back pain almost doubled from 277 in 1994 to 402 in 2003. The number of incidents rose from 9 to 44 over the nine year period. These incidences can increase the risk of claims against the company and workers compensation costs. The amount of days lost for RTG drivers, due to LBP, has significantly increased from 412 days in 1994, to 1908 days in 2003.

Table 4: POF absenteeism figures for Quayside Gantry crane drivers

Quayside Gantry crane drivers					
Year	Lower back		Total days lost for the year (MS)	Total days sick	No. of employees
	No. of occas.	Days lost			
1994	9	277	349	580	1841
1995	7	53	191	729	1830
1996	10	207	254	764	1821
1997	15	212	377	873	2094
1998	21	189	648	1326	2399
1999	30	381	815	2022	2463
2000	31	715	917	2090	2543
2001	32	631	1367	2475	2527
2002	41	845	1218	2455	2444
2003	44	402	616	1677	2677

Table 5: POF absenteeism figures for RTG crane drivers

RTG crane drivers					
Year	Lower back		Total days lost for the year (MS)	Total days sick	No. of employees
	No. of occas.	Days lost			
1994	20	412	1114	1880	1841
1995	25	630	1061	2214	1830
1996	27	366	926	2149	1821
1997	43	530	1377	3639	2094
1998	49	717	1928	4150	2399
1999	109	1480	3898	6517	2463
2000	91	1773	3245	6854	2543
2001	93	1499	2944	6124	2527
2002	129	1516	3537	8013	2444
2003	131	1908	3418	7498	2677

The RTG driver's occurrences of LBP rose steadily from 20 in 1994 to 131 in 2003, despite developments in ergonomics, health and safety, and advances in crane technology. Although the total days lost for musculoskeletal (MS) cases for RTG drivers rose steadily in the 9 years, LBP absence accounted for 37% of total days lost for MS causes, in 1994. However, in 2003, LBP absence increased to account for 56% of the total days lost for MS injuries. The rise in LBP cases and associated loss in production is not relative to the increased number of people being employed by the POF over the nine year period.

It is clear to see that LBP is an enormous problem, affecting almost everyone at least once in his or her lifetime. Although only a few of these back pain suffers will develop a chronic condition, it is this subgroup that presents such an economic burden to industries. Medical care, treatment costs, compensation and loss of productivity all adds to the mounting costs. However, these can be curbed through effective prevention, correct diagnosis, treatment and management. Companies are continuing to seek new ways of reducing injury and associated loss, through management of musculoskeletal injuries.

LOW BACK PAIN MANAGEMENT

1. Functional Anatomy

An upright posture while standing and ambulating is unique to humans. In order to meet the dynamic functional demands, the human spine has a doubled S-shape in the sagital plane with a sharp bend between the sacrum and the lumbar spine.

In normal posture, the line of weight is perpendicular through the centre of gravity. Posture and movement are related to the musculature of the back, which has two functions. Firstly, the musculature is essential for holding the central supporting organ of the body (the spinal column), in its proper shape and position. Secondly, muscles supply the force of its movement.

The muscles situated near the body's surface and far from the midline are highly effective as motor agents, whereas the muscles situated adjacent to the spinal column are mainly concerned with maintenance of posture (Giles & Singer, 1997:4).

The human lumbar spine seems a highly advanced structure but, despite this, LBP, with or without sciatica, is only secondary to the common cold in its frequency, and affects most adults at sometime in their lives. It is the main cause of disability and expense from work related conditions, and is one of the main causes of absence from work.

Muscle weakness due to lack of exercise or disease can affect the spinal curves and cause postural defects. Faulty spinal joint mechanics and LBP may play a role in production of pain. Limited range of motion (ROM), and stiffness of muscles or joints, can all lead to weakness in certain areas, and therefore eventually compensation and strain in other regions.

The vertebral column is made up of 33 vertebrae that articulate at intervertebral joints, allowing for partly rigid, partly flexible support for the trunk (Moore, 1992:323; Fehrsen-Du Toit, 2005:21). The lower back region consists of five lumbar vertebrae, which are stouter and stronger than the other vertebrae. They have a kidney shaped body to bear the load of the upper body and its movement. It has a large oval-shaped vertebral body, and a back component consisting of the facet joint surfaces, transverse processes, spinal canal and spinous process.

1.1 Intervertebral Discs

The vertebral discs lie in between the vertebrae to help absorb weight and pressure, and distribute shock. The outer structure consists of the annulus fibrosis, and the inner part consists of the nucleus pulposus. Internal disc pressure depends on the position of the vertebral column and posture of the back (Fehrsen-Du Toit, 2005:23; Arnheim & Prentice, 2000:699).

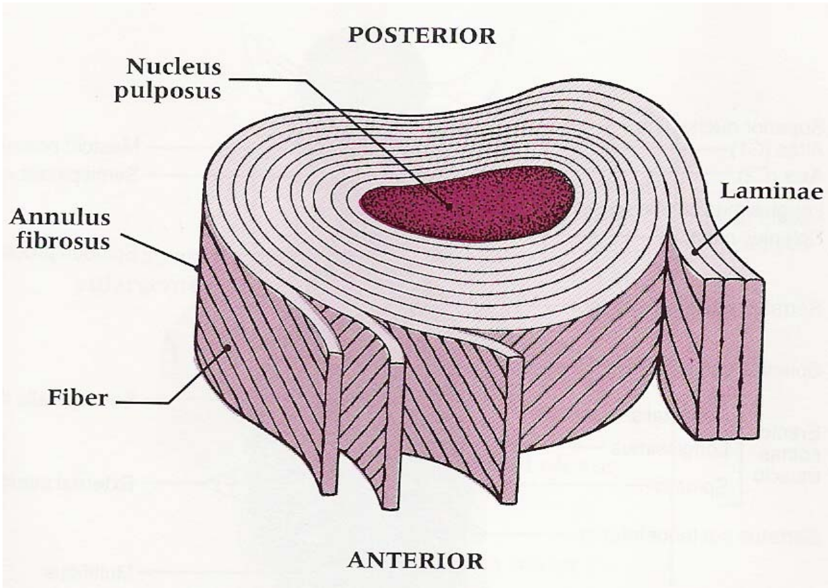


Figure 1: Intervertebral disc (Arnheim & Prentice, 2000:699)

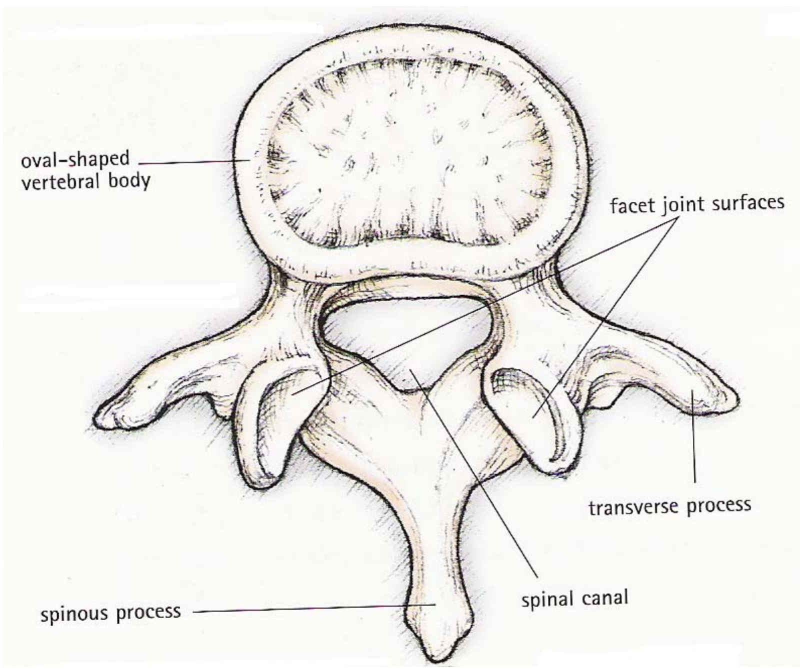


Figure 2: The Lumbar vertebrae (Fehrsen-Du Toit, 2005:22)

1.2 Facet Joints

Facet joints are plate-like structures that join the vertebrae together. The angle of the facet joint varies between vertebrae; and this allows for the control and regulation of movement (Fehrsen-Du Toit, 2005:25).

1.3 Ligaments

The fibrous bands or sheets of connective tissue linking two or more bones, cartilages or structures are known as ligaments. These prevent excessive range of movement, and play a role in stability during movement and at rest. There are six main ligaments in the back, and consist of ligaments between the vertebrae, and ligaments that span a group of vertebrae (Ferhsen-Du Toit, 2005:28; Arnheim & Prentice, 2000:699).

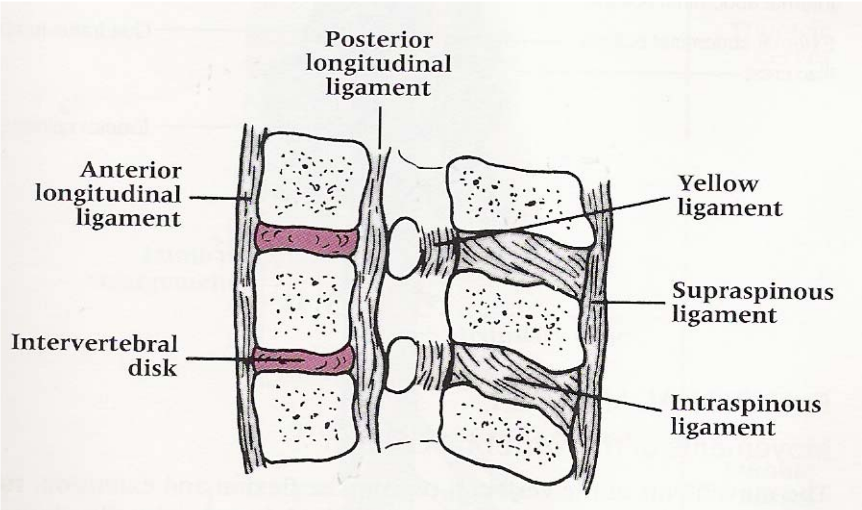


Figure 3: Ligaments of the spine (Arnheim & Prentice, 2000:699)

1.4 Musculature

The muscles of the spine can be divided into five general groups. These muscles work in different combinations to perform extension, flexion, lateral flexion and rotation. The larger muscles are more active in dynamically moving the spine, while the smaller, deeper muscles play an important role in stabilising the spine, and controlling pelvic tilt (Fehrsen-Du Toit, 2005:28). Although each of these muscles is going to be looked at independently, it is important to remember that the lumbo-pelvic-hip complex requires a synergistic, interdependent function of these muscles, to achieve stability and neuromuscular control (Prentice & Voight, 2001:263).

1.4.1 Superficial layer

This group includes the erector spinae, latissimus dorsi, spinalis group, longissimus groug and illiocostalis group. These are the main extensor muscles of the spine, but they also function to laterally bend the trunk, neck and head (Shuenke, 2005; Kendall *et al.,* 2005:176; Kahle, 1992). Not only does the erector spinae group provide intersegmental stabilisation, but it also plays an important role in eccentric deceleration of trunk flexion and rotation in kinetic-chain activities (Prentice & Voight, 2001:261).

1.4.2 Deep layer

The deep muscles of the spine interconnect and stabilize the vertebrae. These include the semispinalis group, multifidus, rotators, interspinalis and intertransvesarii. In various combinations, these muscles produce slight extension and rotation to the spinal column (Shuenke, 2005; Kendall *et al.,* 2005: 176; Kahle, 1992). They are relatively small and therefore designed mainly for stabilisation (Prentice & Voight, 2001:260).

1.4.3 Spinal flexors

These include the quadratus lumborum, longus capitis and longus colli (Shuenke, 2005; Kahle, 1992). Quadratus lumborum works mainly in combination with gluteus medius and tensor fascia lata, as a frontal plane stabiliser (Prentice & Voight, 2001:261).

1.4.4 Abdominal muscles

The muscles of the abdominopelvic area consist of the external and internal oblique, the transverse abdominus (TrA) and rectus abdominus. Except for the TrA, these are dynamic muscles, which flex, and rotate the spine. The rectus abdominus dynamically contracts to perform flexion of the spinal column. The thorax will move towards the pelvis, if the pelvis is fixed, and visa versa if the thorax is fixed. The rectus abdominus also works eccentrically to decelerate trunk extension and lateral flexion

(Prentice & Voight, 2001:262). The external oblique and internal oblique muscles will flex and rotate the spine and tilt the pelvis. They work eccentrically to decelerate the trunk in extension, rotation and lateral flexion (Prentice & Voight, 2001:262). TrA functions to flatten the abdominal wall, provide dynamic stabilization against rotational and translational forces, compress the abdominal viscera and provide optimal neuromuscular efficiency to the entire lumbo-pelvic-hip complex. The contraction of TrA works in a feed-forward mechanism, which precedes the initiation of limb movement and other abdominal muscles. The TrA, along with multifidus has an important role in dynamic stabilisation, as they are both active during all trunk movements (Shuenke, 2005; Kendall *et al.,* 2005:194; Prentice & Voight, 2001:262; Kahle, 1992).

1.4.5 Hip muscles

The gluteus maximus muscle extends, laterally rotates and assists in adduction of the hip joint, as well as helps to stabilize the knee joint. It also plays a major role in stabilisation of the sacroiliac joint, or SIJ (Prentice & Voight, 2001:263). The gluteus medius contracts to abduct the hip, and assists in flexion and extension of the hip joint. Gluteus medius abducts, medially rotates, and assists in flexion of the hip joint. Lateral rotation of the hip joint is brought on by the piriformis muscle (Shuenke, 2005; Kendall, 2005: 194; Kahle, 1992). The psoas muscle performs hip flexion and external rotation, as well as extension and lateral flexion of the lumbar spine. It contracts eccentrically to decelerate hip extension and internal rotation. A tight psoas can increase the anterior shear and compressive force at L4-L5. Flexion of the knee, extension of the hip and rotation of the tibia, are all brought on by the concentric work of the hamstring muscles (Prentice & Voight, 2001:263).

1.4.6 Pelvic floor muscles

The pelvic floor muscles extend from the sacrum and coccyx to the ischium and pubis. Their function is to support the organs, flex the sacrum and coccyx, and control the movement of materials through the urethra and anus (Shuenke, 2005; Kendall, 2005:195; Kahle, 1992). There is some evidence of co-contraction between the muscles of the pelvic floor, TrA and multifidus (MacDonald *et al.,* 2006).

1.5 Load Bearing

The degree, to which the vertebrae bear or fail to bear compressive loads, is determined by the shape and architecture of the vertebral bodies. The wall of the vertebrae remains rigid under compression, but the nucleus of the disc pressurises and causes the cartilaginous end plates to bulge inward, and seems to compress the cancellous bone (McGill, 2002:46). The load on these vertebrae is also determined by the correct functioning of the surrounding dynamic and supportive musculature.

The lumbar vertebrae use a shock absorbing and load bearing system. In recent research, the vertebral bodies, rather than the discs, appear to have a dominant role in shock absorbing function. Bulging end plates suggest fluid expulsion from the vertebral bodies, more specifically blood through the perivertebral sinuses. This is allowed through the columns of bone running vertically from end plate to end plate. As the end plates bulge into the vertebral bodies, with axial compression, these columns appear to bend (McGill, 2002:46).

Excessive pressure can cause the transverse trabuclare to fracture, as the bending columns buckle. The cancellous fracture tends to heal quickly, and regains its original structure and function quicker than the collagenous tissues (McGill, 2002:47). Highly repetitive loads, even at low magnitudes, could cause micro damage.

2. Assessment

2.1 Objective Assessment

Back assessments should be standardized and systematic, although it is still important to remember that back pain, especially mechanical back pain, is usually multifactoral. This is what makes a complete case history so essential in any assessment. This usually takes into account the patient’s age, occupation, medication, previous injuries, onset of pain, recreational activities, the characteristics and frequency of pain, and any related neurological symptoms (such as numbness, paraesthesia, weakness). This can lead to diagnosis of conditions, which have relatively characteristic patterns (Giles & Singer, 1997: 324). Factors such as smoking, weight loss and cancer need to be taken into consideration, and can aid in risk of malignancy (Carragee & Hannibal, 2004).

2.2 Subjective Assessment

The clinician's physical evaluation should be orderly and systematic (Giles & Singer, 1997:325) and should include certain elements, which help to exclude certain conditions and lead to an accurate diagnosis. It can include a subjective pain assessment using pain scales and diagram, as well as an objective examination of special tests, observations, postural examination and palpations. The use of simple psychological questionnaires has also proven to be of great value (Giles & Singer, 1997:331; Jacob *et al.,* 2001; Reneman *et al.,* 2002; Kopec & Esclaile, 1995). A combination of these components will lead to an accurate evaluation, diagnosis, and relevant treatment.

Diagnoses of LBP can be divided into three major categories, according to Carragee & Hannibal (2004):

Mechanical

Osteoarthritis, spinal stenosis, spondylosis, compression fracture

Non-mechanical

Tumour: Metastases, Lymphoma, Giant cell tumour

Infection: Vertebral osteomyelitis, Diskitis, HIV

Inflammatory arthritis: Rheumatoid arthritis, Ankylosing spondylitis

Miscellaneous: osteoporosis, parathyroid disease, neuropathic joints, psychosomatic disorders

Visceral disease

Nephrolitthiasis, prostatitis

The physical examination should assess spine symmetry, posture and flexibility to determine causes of mechanical LBP. ROM should be assessed, palpating muscular structures and spinous process can identify abnormailities and spasm, and a full neurological exam should be completed (Carragee & Hannibal, 2004).

Incidences of LBP have been associated with several clinical factors. These include lumbar lordosis, pelvic tilt, leg length discrepancy, foot pronation, length, strength and endurance of muscles in the trunk and lower extremity (Rone-Adams *et al.*, 2004; Bayramoglu *et al.*, 2001). These are essential components to consider and examine in a physical evaluation. Rone-Adams *et al.*, (2004) found that 15% of Physical Therapists evaluated trunk flexors during their assessments, despite the fact that several studies have indicated that weak abdominals play a role in lumbar lordosis and pelvic tilt, as well as being associated with the cause of LBP (Bayramoglu *et al.*, 2001; Batt & Todd, 2000).

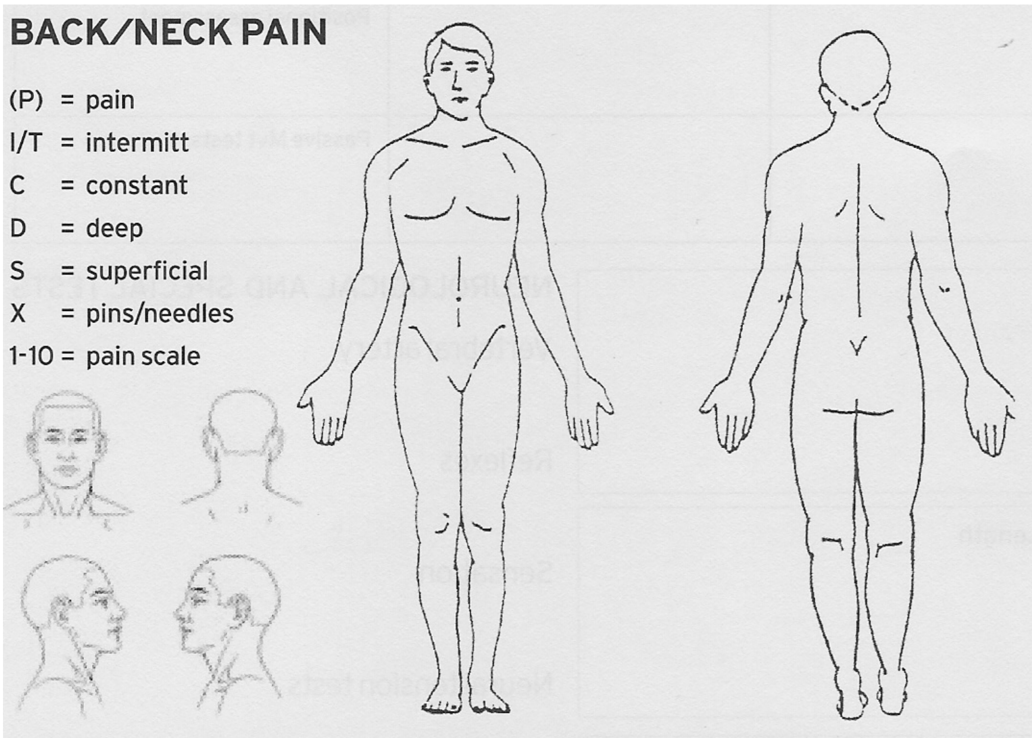


Figure 4: Subjective pain rating diagram (example)

A precise pathological cause is not given for approximately 80% of LBP sufferers (Poitras *et al.,* 2000; Spratt *et al.,* 1990). This leads to the conclusion that measurement of disability and accurate evaluation remains a challenge in the health care system (Poitras *et al.,* 2000).

Although spinal kinematics such as range of movement, velocity and acceleration have been indicated in LBP, they were not conclusive as a valid measure of disability in LBP patients, but do have some value in screening for risk factors (Poitras *et al.,* 2000).

The use of Waddell Signs can also be significant in prognosis (Carragee & Hannibal, 2004; Polatin *et al.,* 1997) and can be used in predicting return to work for CLBP patients. The five non-organic Waddell signs include:

Tenderness

Superficial: Widespread sensitivity to light touch of skin over lumbar spine.

Nonanatomic: Bone tenderness over a wide area, often extending to the thoracic spine, sacrum or pelvis.

Simulation

Axial Loading: Increase of LBP with light pressure to skull when standing.

Rotation: Increase of LBP with passive rotation of shoulders and pelvis in same plane, in the standing position.

Distraction

Inconsistent findings in sitting versus supine straight leg raise.

Regional disturbance

Motor: Generalised giving way or resistance in manual muscle testing.

Sensory: Non dermatomal loss of sensation in pinwheel testing of the lower extremities.

Overreaction

Disproportionate pain response to testing such as:

- Assisted movement

- Rigid or slow movement
- Bracing: both limbs supporting weight while seated
- Rubbing affected area for more than 3 seconds
- Clutching, grasping affected area for more than 3 seconds
- Grimacing
- Sighing with shoulders rising and falling (Polatin *et al.,* 1997).

A high Waddell score is usually associated with yellow flags, or abnormal illness behaviour. This suggests further investigation, and a mental health assessment is recommended.

3. Cause

3.1 Occupation

The majority of people living in Europe and North America have a large chance of suffering from a disabilitating back injury or pain, despite their occupation. Occupational factors have, however, been shown to further increase the chance of LBP (Seidler *et al.,* 2003; Burdorf, 1997; Burdorf *et al.,* 1993; Burdorf & Zondervan 1990). Factors such as heavy physical loading, prolonged sitting and sustained non-neutral work postures (Burdorf *et al.,* 1993) and vehicular driving have been associated with lower back pain, and spinal degeneration (Videman & Battie, 1999; Bernard, 1997:374). Associations have been drawn between extreme or prolonged forward flexion with disc herniation (Seidler *et al.,* 2003). In a study by Hoogendoorn *et al.,* (2000), extreme trunk flexion was found to be a risk factor in lower back pain particularly when the trunk is in a minimum of 60 degrees of flexion for more than 5% of the working time.

Lower back pain is a risk factor for RTG crane drivers due to their working postural position (Burdorf *et al.,* 1993), with an unfavourable flexed position that can lead to neck and back problems. The viewing demands dictate the crane driver's working posture. A long period of time is spent looking downwards. The driver's working posture can, therefore, involve slight to extreme back and neck flexion for prolonged periods of time, making them vulnerable to neck and back pain. Frequent bending and whole body vibration are proven risk factors in back conditions (Burdorf, 1997). Burdorf and Zondervan (1990) found an elevated occurrence of lower back pain in crane drivers, who were exposed to heavy lifting, and prolonged sedentary posture, compared to non crane drivers.

3.2 Risk Factors

LBP is a common health complaint of 60-80% of adults (Nourbakhsh & Arab, 2003; Carter & Birrel, 2000:6; Bernard, 1997:374). It is often persistent and frequently recurrent, and has become one of the most common reasons for work loss and for seeking health care or treatment (Carter & Birrel, 2000:6).

Certain activities, especially those that force the trunk into a non-neutral position, can cause an increase in disk pressure, and therefore increase the risk for LBP, particularly if this position is held for prolonged period of time. A bar graph indicating an increase in disk pressure is shown in Figure 5 below.

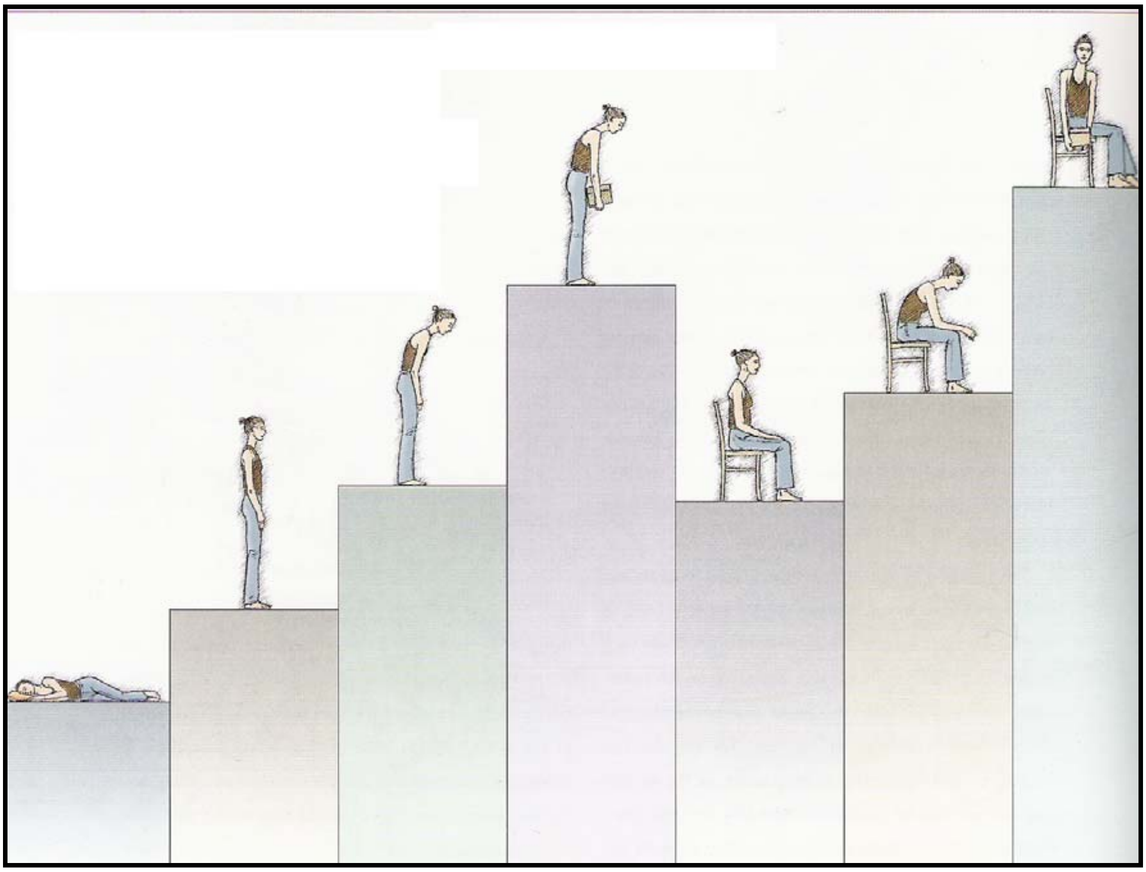


Figure 5: The increases in disk pressure with different activities (Fehrsen-Du Toit, 2005:24; Nachemson, 1963a)

Although LBP is affected and caused by various psychosocial, occupational and unidentified factors (Moshe & Levin, 2005; Van Nieuwenhyse *et al.,* 2004), it is widely known and accepted that physical demands of work contributes greatly towards onset, recovery and reoccurrence of symptoms (Carter & Birrel, 2000:6).

The following factors are emphasised as occupational factors in LBP (Carter & Birrel, 2000:6; Elders & Burdorf, 2001; Burdorf, 1997; Videman & Battie, 1999; Bernard, 1997:374).

3.2.1 Heavy physical work

Heavy physical work can be defined as work that requires a certain prerequisite of physical strength, or involves high energy demands. It can include tasks such as manual material handling, tiring heavy or dynamic work. Manual moving and lifting of materials or people is associated with LBP (Carter & Birrel, 2000:6; Elders & Burdorf, 2001; Smedley *et al.,* 1995; Bos *et al.,* 2002; Nourbakhsh & Arab, 2002;

Bernard, 1997:376). Crane operators were significantly more likely to develop LBP, than workers who did not operate cranes, in a study by Burdorf & Zondervan (1990) at a Dutch steel plant. Mooney *et al.,* (1996) found a higher incidence of LBP in shipyard workers that were involved in heavy or very heavy work

Reports of LBP, severe LBP, CLBP and disability due to LBP, was consistently associated with physical loads in the workplace (Elders & Burdorf, 2001).

In a review of the epidemiologic research by Bernard (1997:376), for the National Institute for Occupational Health and Saftey (NIOSH), exposure to heavy physical work showed low to moderate increased risk of low back disorders. Despite mixed definitions and assessment of pain and work, there was still undoubtly a positive correlation between risk of LBP, and exposure to heavy physical work.

3.2.2 Lifting and forceful movements

Lifting can be defined as transferring objects from one plane to another. Forceful movements include the movement of objects by means of pushing, pulling, or other efforts. There is strong evidence to suggest LBP is associated with lifting at work or forceful movements (Trinkoff *et al.,* 2003; Bos *et al.,* 2002; Carter & Birrel, 2000:6). Biomechanical and laboratory tests provide evidence regarding the effects of lifting and dynamic motion on back tissue, and are consistent with the research suggesting both lifting and awkward postures contribute to low back disorders (Bernard, 1997: 385).

The load's weight is also a risk factor, and Hoogendoorn *et al.,* (2000) found that lifting 2.5kg or more increased the risk of LBP, when this occurred more than 15 times in a working day, with the risk increasing with the frequency. Flexion and rotation combined with lifting further increased the risk of LBP.

3.2.3 Awkward postures

Bending can be defined as flexion of the trunk, in a forward or lateral direction. Twisting is referred to as trunk rotation or torsion. Any posture that is in an extreme angle or position from neutral can be described as an awkward posture. These can include kneeling, squatting or stooping. Literature results are consistent with exposure to awkward positions and LBP (Carter & Birrel, 2000:6; Bernard, 1997:393; Smedley *et al.,* 1995).

Low back disorders are associated with postures that required maintaining trunk flexion. These associations were shown to increase with increased degree of flexion. Mild trunk flexion is defined as the trunk flexed forward from 21º to 45 ̊ and produced an odds ratio of 4.9. Postures involving maintaining severe trunk flexion (defined as the trunk being flexed forward to greater than 45̊°) produced an odds ratio 5.7. Postures involving twisting or lateral bending of greater than 20̊ produced an odds ratio of 5.9. Their results suggested that the risk of back injury increased with the exposure to these deviated postures and with increased duration of exposure. Deviated postures greatly increase low back tissue loading, particularly when they must be held for prolonged periods (Marras *et al.,* 1995; McGill, 2002:60; Nachemson, 1963a; Nachemson, 1963b).

Associations have been drawn between extreme or prolonged forward flexion with disc herniation (Seidler *et al.,* 2003). In a study by Hoogendoorn *et al.,* (2000), extreme trunk flexion was found to be a risk factor in lower back pain particularly when the trunk is in a minimum of 60° of flexion for more than 5% of the working time.

3.2.4 Whole body vibration (WBV)

Exposures to driving or operating industrial vehicles can result in mechanical oscillations, which are transferred to the body as a whole. It is one of the most common occupational hazards in Britain (Palmer *et al.,* 2003). WBV has an effect on the vertebrae, intervertebral discs and musculature. This supports the strong evidence of WBV associations with LBP. Experimental and epidemiological evidence suggests WBV combined with prolonged sitting, lifting, awkward postures and other work place factors causes an increased risk in MSD (Bernard, 1997:398). There is growing evidence to suggest that regular vibration and jolting contributes to LBP found in drivers, fork lift truck drivers, crane operators, helicopter pilots (Palmer *et al.,* 2003) and rally drivers (Mansfield & Marshall, 2001).

A review of the literature by Chambers (2001) found controversial evidence between the causal relationship with WBV and LBP, and suggested that LBP involves both occupational and non-occupational factors.

Palmer *et al.,* (2003) found that risk of LBP in Britain was more likely to be caused by lifting at work rather than WBV. However, there is not an absence of risk in occupations that are exposed to WBV on a daily and frequent basis. Reports of lumbar discomfort in rally drivers (70% of the participants) seemed to increase with increased exposure to WBV (Mansfield & Marshall, 2001). LBP is definitely associated with exposure to WBV and lifting at work, but the causal relationship is not agreed upon. In a national study, 444 000 cases of LBP in men could be attributable to WBV, which was considerably less than the cases caused by lifting (940 000), which could be due to the fact that more occupations in Great Britain involve lifting than prolonged exposure to WBV (Palmer *et al.,* 2003).

3.2.5 Static work postures

A static work posture can involve very little movement, but can include isometric positions, and static loading of the muscles. A static work posture has been associated with lumbar disc pathology, although Bernard (1997:406) found inadequate evidence to support this suggestion.

Biomechanical and laboratory tests provide evidence regarding the effects of lifting and dynamic motion on back tissue, and are consistent with the research suggesting both lifting and awkward postures contribute to low back disorders.

Furthermore, the nature of lower back disorders appears to be affected by the type of work. Videman & Battie (1999) noted a tendency among those who had had sedentary careers had a tendancy to have marked disc degeneration in later years. Those who had performed heavy work (defined as not only lifting but also requiring large trunk motions) tended to have classic arthritic changes in the spine (stenosis, osteophytosis, etc.). There is evidence to suggest that a sustained non-neutral posture is a risk factor for LBP (Beach *et al.,* 2005; Sanyo & Ogwumike, 2005; Burdorf *et al.,* 1993; Burdorf & Zondervan, 1990), specifically disk herniation (Videman & Battie, 1999).

The literature suggests that the cause of LBP is multifactoral (Moshe & Levin, 2005; Van Nieuwenhyse *et al.,* 2004; Hoogendoorn *et al.,* 2000; Papgeorgiou *et al.,* 1997). Significant relations were found between physical and psychosocial loads, and perceived health (Elders & Burdhof, 2001). Therefore it is suggested that all factors need to be considered in the cause of back pain, but that there is consistent evidence to support the suggestion that there is a definite increase in risk with occupations involving the above mentioned factors. Studies suggest that several cofounders such as age, smoking habits, education, job satisfaction, stress and responsibility all contribute towards the complexity of LBP (Hoogendoorn *et al.,* 2000; Burdorf, 1997).

Crane drivers in particular are exposed to all of the above risk factors, and are considered at risk when it comes to LBP. The prevalence of LBP in crane drivers was measured at 50% for a 12 month period, and was higher than that of straddle-carrier drivers (44%) and office workers (34%) (Burdorf & Zondervan, 1990). Factors such as job satisfaction, socio-economic status and fear avoidance, complicate the issues of LBP and absence for crane drivers.

3.3 Prevention

Prevention strategies have been widely acknowledged in the scientific and industrial world, although it is yet to be implemented at an organisational level. In most clinical practises, there is a traditional disease/treatment model of practise, which can be fundamentally limiting to prevention strategies. Companies with a high number of employees performing physical jobs, often lack effective prevention strategies. These companies are often dependant upon governmental health systems where treatment can be hindered by long waiting lists, and ineffective care.

Prevention strategies can be divided into primary, secondary and tertiary prevention (Amell & Kumar, 2001)

1.	Primary prevention	The main goal is to prevent the illness or injury from occurring in the first place. This is done through analysis of work place and tasks,

		adhering to health and safety. It can also involve implementing a pre-screening programme for heavy physical work tasks.
2.	Secondary prevention	This involves early detection and treatment of asymptomatic injuries before symptoms occur.
3.	Tertiary prevention	The goal is to make sure that the existing injury does not reoccur. This is done through accurately assessing work place and tasks for risk factors, and ergonomic risks.

All three prevention strategies involve changing work places, incorporating the use of aids, tools and phased return to work programmes. Ergonomic assessments and the introduction of workplace interventions have been shown to decrease the incidence of musculoskeletal disorders in the work place (Smedley *et al.,* 1995; Trinkoff *et al.,* 2003).

Injury reduction through pre-screening has been seen to reduce incidences of overexertion injuries in truck drivers and dockworkers (Gilliam & Lund, 2000).

The POF has focused on preventative measures at an industrial level, incorporating the use of Injury Prevention and Rehabilitation Services (IPRS) to address these concerns. Prevention programmes have included thorough ergonomic studies of RTG drivers, and development of pre screening protocols. It has taken a multidisciplinary approach, incorporating ergonomics, physiotherapy, rehabilitation, occupational health and health and safety. This approach is accepted as having the greatest effect on management of work related musculoskeletal injuries (Amell & Kumar, 2001).

It is recommended that ergonomic and human factors design principles, and assessment of the workplace's physical and psychological risk factors be used in prevention strategies (Amell & Kumar, 2001; Carter & Birrel, 2000:8).
Physical factors such as general exercise routines may reduce future LBP and work loss (Carter & Birrel, 2000:8). Psychosocial job aspects and job satisfaction is

associated with low disability and sickness absence rates (Carter & Birrel, 2000:8), and needs to be considered along with the physical aspects. Assessment of each of the many factors associated with workplace LBP will in turn be the most effective way to manage this ongoing problem.

Worker education and interventions may reduce work loss by creating a safety conscience work environment (Carter & Birrel, 2000:8).
Prevention has also begun to focus on reducing long term absence from work. It is believed that 90 % of all back pain sufferers will recover in 6 weeks, and therefore prevention is aimed at reducing long term sick and disability. This is done by identifying workers who are at risk for long periods of sickness absence (Elders & Burdorf, 2004) and developing ways to return them to work, and prevent long term disability and claims.

Evidence based care is essential for managing LBP properly. Long periods of absence, best rest and the use of lumbar belts (Carter & Birrel, 2000:8), have not been accepted as a way to reduce or prevent LBP.

3.4 Outcome Measures

The success of treatment and prevention strategies are usually measured by certain outcome measures such as physical capability, functional abilities, job satisfaction, absenteeism, perception in pain, lifting performance, patient attitude and costs (King, 1993; Dionne *et al.,* 1999; Deyo *et al.,* 2005; Bardin, 2002; Tayeyachi *et al.,* 2003).

Schaufele & Boden (2003) set these outcomes into five domains, namely:

3.4.1 Back specific function

This is to determine the patient's perception of the degree of symptoms, and functional limitations caused by their LBP. This is most commonly assessed by questionnaires such as the Roland-Morris Disability Questionnaire (Jacob *et al.,* 2001) and the Owestry Disability Index (Reneman *et al.,* 2002; Kopec & Esclaile, 1995). These are subjective measurements, and should be combined with an objective examination (Poitras *et al.,* 2000; Wittink *et al.,* 2003), as outcomes are related but not synonymous.

3.4.2 Generic health status

This is an indicator of the patient's perception of their capabilities to function in general life activities. The Short Form-36 Health survey, or the shortened SF-12 version, is used as a valid measure of limitations in the patient's ability to function socially and actively due to physical and emotional problems (Luo *et al.,* 2003).

3.4.3 Pain measurement

This involves the sensory aspects of pain, as well as the person's emotional reaction to the pain.

3.4.4 Work disability

Outcome measures help to assess loss of productivity, effectiveness of health service and financial costs. It can also help in designing prevention strategies, and track changes in the occupational environment.

3.4.5 Patient satisfaction

Interaction with the health care provider and treatment satisfaction is an important outcome measure.

A set of standardized outcome measures and questionnaires are available for each domain, which allows for accurate and effective outcome measure research, as well as in a clinical setting (Schaufele & Baden, 2003). Physiotherapists should use outcome measures that are clinically appropriate, functionally relevant and reflect the broad biopsychosocial impact of LBP (Bardin, 2002)

Although there is a strong correlation between pain, functional limitations and work status, and although they are related, they can not be used as interchangeable terms (Dionne *et al.,* 1999).

There has been some evidence to suggest that back schools, education and exercise programmes, can lead to an increase in physical capacity, functional ability and trunk muscle strength (King, 1993). Pain related fear can also often be a factor in activity avoidance, and can affect performance in functional assessments (Geisser *et al.*, 2000).

In a systematic study of the literature on preventative strategies, King (1993) found that generally, primary prevention programs lead to a decrease in financial costs, and incidence in LBP. Secondary prevention programmes were found to facilitate a positive change in the attitudes, psychological and physical well being of the patient, and an improvement in functional abilities.

4. Occupational Pre-screening

There is strong evidence to suggest that a history of LBP is the best predictor for future problems, even more so than examination, X-rays, back function testing and psychosocial screening. It is suggested that considering frequency and duration of LBP episodes, radiating leg pain, previous surgery and sickness absence, for pre-employment placement is essential for a physically demanding job (Carter & Birrel, 2000:7). However, LBP can not be a reason for denying employment, although it is strongly suggested that necessary precautions be taken when employing individuals with a strong history of back pain into a physically demanding job.

There is evidence to prove that occupational and physical demands do stress our bodies, and apply loads to the lower back. It is therefore necessary in a physical demanding job, to develop a pre-screening protocol to assess norms and functional capabilities. This is also used as a preventative measure in minimising the chance of LBP occurring in the future. Although pre-screening research is controversial, there is evidence to believe that isokinetic evaluations for new employees can decrease the amount of overexertion injuries (Gilliam & Lund, 2000).

For pre-screening to be a successful measure in prevention, specific job demands need to be defined. The maximal acceptable load of an employee needs to be assessed when job demands involve heavy physical work, pushing, pulling or lifting. Bos *et al.*, (2002) recommend tests concerning specific occupational demands to be a part of a pre-employment testing or health surveillance, for intervention on an individual level.

These job specific tests should be of good quality, reliable, having prognostic value and content validity.

A Functional Capacity Evaluation (FCE) can also have some value in assessing an employee's ability to work in a safe and productive manner, and can be useful in evaluating treatment outcomes, and returning to work (Brouwer *et al.,* 2003). These tests usually consist of ROM, strength testing and simulation of specific job tasks (Ferguson *et al.,* 1996) but these tests can be time consuming and involve space and equipment. It is not always possible or practical to simulate job tasks, especially in the case of RTG crane drivers.

Assessment of strength, flexibility and stability are essential for pre-screening in a job with physical demands. Reduced trunk strength and physical fitness are predictors for LBP (Batt & Todd, 2000; Bayramoglu *et al.,* 2001), and are important in a functional capacity assessment of the lumbar spine (Tollison & Kriegel, 1989:346). Pre-employment screening can be a useful tool in highlighting physical, occupational, and social risk factors. It enables companies to implement prevention strategies without discriminating against employees.

4.1 Assessment

Assessment in occupational health management of an injury is of value, but is limited in predicting vocational outcomes and prognosis. Clinical examinations such as height, weight, straight leg raise (SLR) tests, as well as screening for spinal diseases and nerve root problems are of significant value in clinical management, especially in dealing with acute and chronic conditions. Psychosocial factors are particularly useful in determining those who are at risk for chronic pain and disability (Carter & Birrel, 2000:8; Carragee & Hannibal, 2004; Spratt *et al.,* 1990).

4.2 Management

It has already been established that LBP is a common and costly condition. However, despite these statistics, few clinicians realise that only 6% of the LBP population will suffer from a disabling LBP. 15% will have a reoccurrence of symptoms in the twelve months following their first episode (Stevenson & Hay, 2004). Management of back pain therefore becomes essential in the initial stages, to prevent it from developing into a costly burden on employers and medical services.

Stevenson and Hay (2004) developed a care pathway for the management of back pain at the Staffordshire Acute Back Pain Service. Research indicates that LBP sufferers recover quicker from symptoms when they are encouraged to return to normal activities as much as possible, despite pain. Workers are encouraged to return to work despite still experiencing residual symptoms. Educational interventions, and understanding can play a crucial role in fear avoidance, return to work, condition management and patient responsibility (Carter & Birrel 2000:8).

Management of LBP needs to include a combination of RTW programmes for management, and pre-screening programmes for prevention.

ERGONOMICS

Ergonomics focuses on optimising the relationship and interactions between humans and their working environments. This is done through the study of work performance, with an emphasis on productivity, while still maintaining worker safety (Jacobs, 1999:10).

Therapy, rehabilitation and ergonomics can work together in contributing towards the prevention of musculoskeletal conditions.

Therefore, ergonomics is crucial in the design of products and environments by creating items and places that enhance productivity, while preventing musculoskeletal injuries of the user (Jacobs, 1999:10). This includes an optimal work place design to encourage correct posture, and minimise strain on muscle, tissues and joints.

1. Posture

Posture is described as the orientation of body parts in space (Jacobs 1999:25), or as the relative arrangement of parts of the body (Kendall *et al.,* 2005:51). It is widely believed to have a profound effect on health and well being.

The human body has the structure to attain and maintain good posture. This good posture can be affected by bad habits, muscle weakness or repetitive activity. The high incidences of postural faults or injuries in adults are usually caused by a specialized or repetitive activity (O' Sullivan *et al.,* 2006; Kendall *et al.,* 2005:51). Correct posture will enable the body to perform activities with the least strain as possible. This can be achieved by maintaining muscular and skeletal balance, by keeping as close to the neutral posture as possible. The body's structures are therefore supported, and risk of injury is reduced.

In order to assess and compare posture, a standard line of reference, or plumb line, is necessary. This divides the body into front and back along the coronal plane, such as in Figure 6.

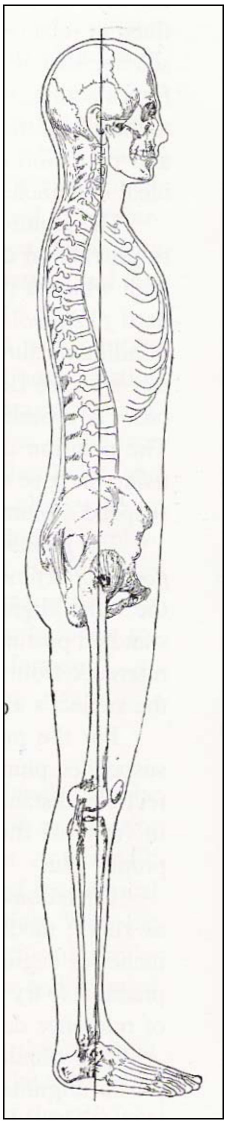


Figure 6: Ideal Plumb alignment from a side view (Kendall *et al.,* 2005:60)

If the body moves forward or backwards away from the coronal plane, it results in flexion or extension of the trunk (Kendall *et al.,* 2005:56). Figure 7 and 8 show the movement of the pelvis in relation to the lumbar vertebrae. Figure 9 depicts lumbar flexion from the coronal plane, which Figure 10 shows lumbar movements and its associated pelvic tilt.

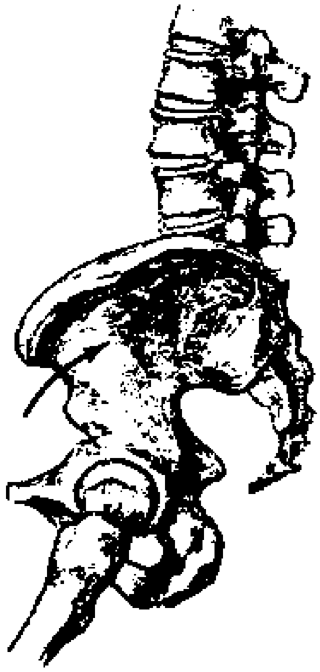


Figure 7: Lumbar extension

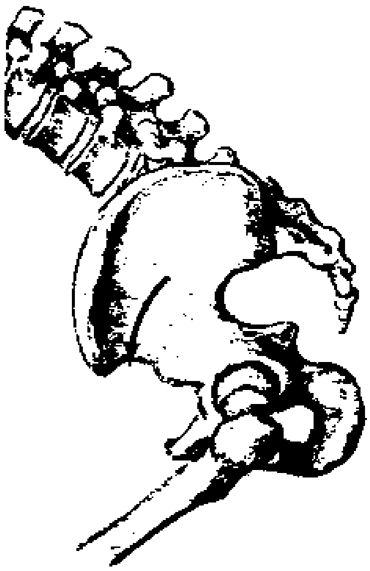


Figure 8: Lumbar flexion

Figure 9 shows the body moving out of the neutral, or state of balance. Figure 12 shows the movement of the lumbar vertebrae with associated sacrum and pelvis movements. Clinical management of back and neck pain includes strategies to rehabilitate postural muscles, and retrain postural form. This has been shown to be more effective when supervised by a clinician (Falla *et al.,* 2006).

Research has shown that posture is affected by fatigue in trunk muscles (Allison & Henry, 2002). A delay in the activation of trunk muscles, that provide the necessary postural adjustments, has been linked to LBP (Moseley & Hodges, 2005).

Figure 9: Flexion and extension from the coronal plane (Kendall *et al.*, 2005:56)

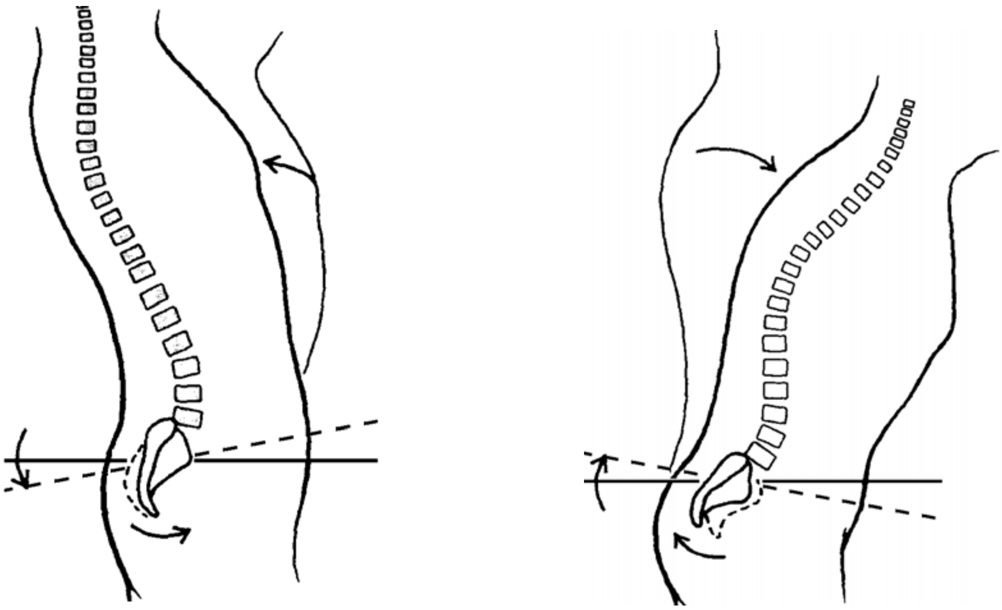


Figure 10: Lumbar extension and flexion and associated pelvic shift

2. Biomechanics

Biomechanics is the foundation for ergonomics. Ergonomics is essential, not only in a home environment, but also in an occupational setting. Occupational ergonomics is essential in improving worker's performance while achieving organisation's productivity. It is used as a tool in the guidance of:

i. Selection of job applicants,
ii. Hand tool design
iii. Workplace design
iv. Machine control layout
v. Seating design
vi. Appropriate material handling limits (Jacobs, 1999:26)

The main tasks of an RTG crane driver involve a seated position, with forward flexion of the neck and back, and the use of controls.

It is necessary to understand the biomechanical relationships between the environment and the worker, and in this study, specifically looking at the spine.
Jacobs (1999:93) describes back pain as stemming from three major causes, namely:

i. Abnormal strain on a normal back
ii. Normal strain on an abnormal back
iii. Normal stress on a normal back that was unprepared

3. Environmental Design

Task performance can be classified into a function of three factors:

i. The person performing the task
ii. The equipment used
iii. Environment in which the two interact (Jacobs, 1999:136).

Figure 11 depicts how the task is a function of person, environment, and system all overlapping to create performance.

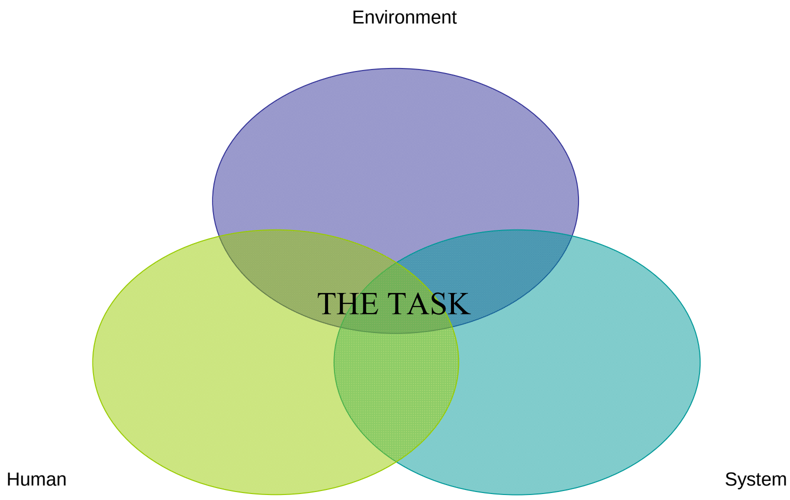


Figure 11: Task performance environment (Jacobs, 1999:136)

Environmental factors, which need to be taken into consideration, include variables such as vibration, noise, illumination and temperature.

For the purpose of this study, the only system equipment that will be looked at in depth is the seat and seating.

4. Seating

Sitting is known to place a great deal of stress on the lower back. There are , however, advantages to sitting when compared to other postures. It decreases the operators fatigue, increases their stability, provides a support from which to exert a force, enables the use of pedals, and accommodates a variety of sizes and heights (Jacobs, 1999:78). However, research reveals that disc pressures are greater in a seated position (Jacobs, 1999:79; Fehrsen-Du Toit, 2005:24). A reclined seating position decreases muscle activity, but largely increases disc pressure. Prolonged static postures increase the stress on vertebrae and soft tissue. It also places the worker at a greater risk for injury. A forward inclination of the head causes an increase in torque from the weight of the head relative to the midline. Therefore it is encouraged that the body parts should be in alignment with each other, without twisting or asymmetry, and a back support should be provided.

The ideal seated posture should include a 90º hip flexion, 90º of knee flexion; 90º elbow flexion, accompanied by a straight back and erect head. The back should allow for 105º of recline (Jacobs, 1999:79). In sitting, most weight or pressure is placed on the ischial tuberosities of the pelvis. A good ergonomic chair design usually focuses on promoting correct posture and worker comfort while increasing productivity and reducing risk of injury. Sitting can, over time, stretch muscles and cause strain on ligaments. Flattening of the lumbar spine during sitting can be a factor in the cause of disc herniation. Disk trouble is also known as the most common cause of back pain in the general adult population (Seidler *et al.,* 2003; Hoogendoorn *et al.,* 2000).

5. Prevention

Cumulative trauma disorder (CTD) or repetitive strain injuries (RSI), consist of physical ailments and injuries caused by repeated mechanical stressors or strains. It can cause wear and tear on the body through forceful exertions, awkward postures and high repetitions. It has been found to account for 60% of work related illnesses (Jacobs, 1999:272).

Guidelines for workplace injury prevention, as recommended by Jacobs (1999:275) include:

1. Risk assessment
2. Work site analysis
3. Hazard prevention and control
4. Training and education
5. Medical management

CRANE DRIVERS

1. Job Task

The main job description is to operate the RTG cranes (specific to the POF) for the purpose of handling containers and other cargo. It includes checking and other related duties to achieve high levels of productivity and customer service. Duties are to be performed with due concern for safety, the minimisation of damage and delay, and in accordance with established operating procedures.

An ergonomic study of RTG cranes used within the port of Felixstowe was done in 2001. This formed part of ongoing programmes by the Port of Felixstowe to support the health and safety of all the drivers. The aim of the study was to highlight ergonomic issues relevant to health and safety, and propose practical measures to improve conditions where necessary (CCD, 2001: *unpublished*).

Figure 12: Port of Felixstowe, UK (Courtesy of the Port of Felixstowe)

2. Definition

RTG's are large mobile gantries that move around the container park in order to load and offload containers from road haulage vehicles and tug master tractor trailers. Their other main task is to retrieve and stack containers within container park rows.

Figure 13: Rubber Tyred Gantry Crane (Shanghai Zhenhua Port Machinery)

Figure 14: Rubber Tyred Gantry Crane (Shanghai Zhenhua Port Machinery)

3. Structural Elements

The crane contains a lifting frame of 25m, which provides access to the cab via ladders and houses drive and operating gear. Four or sixteen rubber tyres attach to the lifting frame via four rotating and steerable wheel units. The driver's cab is under a rail mounted trolley running between frame legs (Figure 17). A header block and spreader (head unit) are set at a distance of 2200mm forward of a fixed cab point (Figure 15).

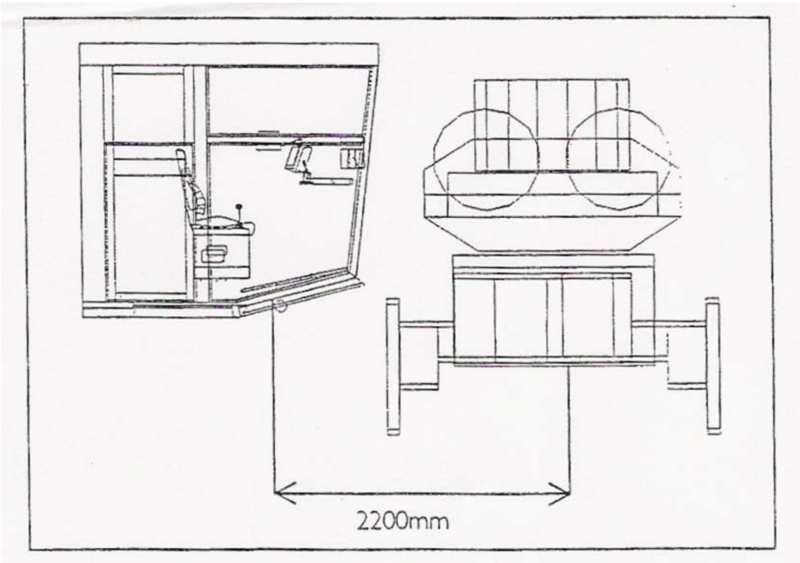


Figure 15: Head unit (CCD, 2001:*unpublished)*

4. Cab Design

The RTG is controlled by a driver, who is accommodated in a cab measuring 2.1m in length x 1.8m in width x 2m in height, which is shown in Figure 16 (CCD, 2001:*unpublished*) and Figure 18.

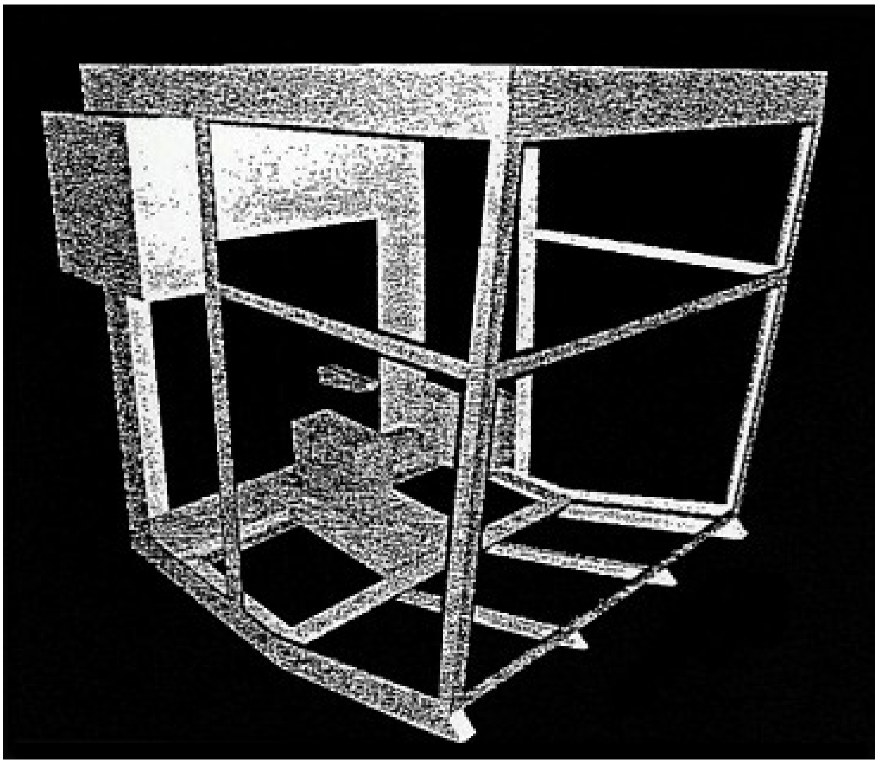


Figure 16: RTG Cab (CCD, 2001:*unpublished*)

Figure 17: Exterior view of the RTG Cab (Shanghai Zhenhua Port Machinery)

Figure 18: Exterior view of the RTG Cab (Shanghai Zhenhua Port Machinery)

Figure 19: Example of a driver's seat (Shanghai Zhenhua Port Machinery)

The cab is glass except for the structural supports, and the following interior elements:

- Driver's seat (Isringhausen 6000 range)
- Spare tip up seat to the rear cab wall
- Primary control consoles on either side of the driver's seat
- Secondary control console located on the rear cab wall
- Touch screen on adjustable arm
- Cab systems screen
- Cab radio with adjustable microphone and commercial radio on left cab wall
- Heaters

- Adjustable foot plates

There are two primary control consoles, located on either side of the driver's seat. These are used for all major driving, container handling, safety controls and indicators (Figure 20).

The left side controls allow the driver to steer and move the RTG, as well as the cab and header unit between frame legs. These also control the attachment/release of the header unit to the container.

Controls on the right side consist of a joystick controlling the speed, direction of the cab, header unit, and RTG movement. It also operates the cab lights.

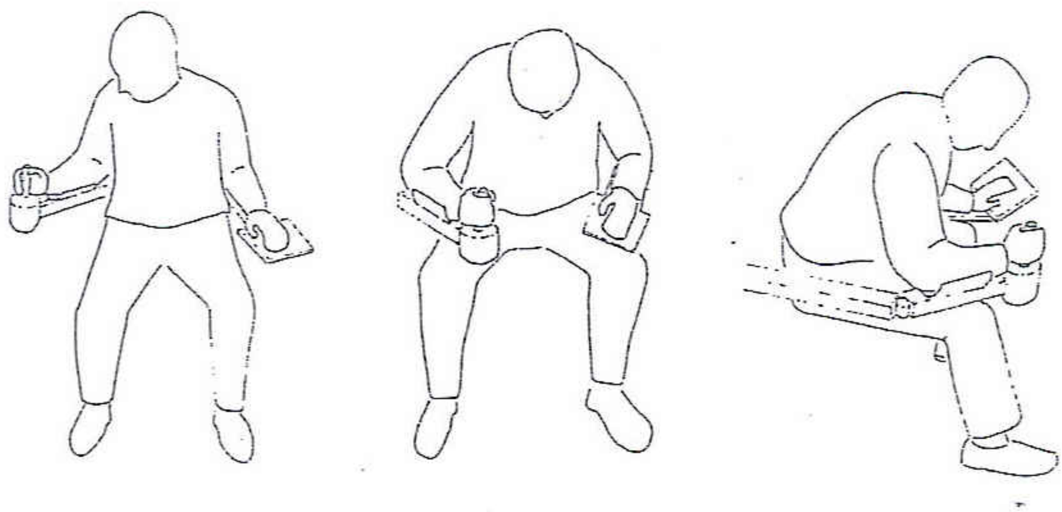


Figure 20: Example of an RTG driver's position (CCD, 2001:*unpublished*)

Figure 21: View from the Cab

The driver's view, as shown from between the driver's legs, looking down onto the container area, can be seen in Figure 21.

The Port of Felixstowe has done extensive research and development of the driver's seat installed in RTG cabs. The Isringhausen 6000 series seat provides the following features and adjustments

- Height adjustment
- Cushion slide adjustment
- Cushion tilt adjustment
- Backrest angle adjustment
- Pneumatic lumbar support adjustment
- Seat suspension adjustment
- Headrest adjustment and design to aid rearwards view
- Armrest retract and height adjustment (CCD, 2001:*unpublished*)

5. Ergonomics

5.1 Risk

There are four identified areas of risk for crane drivers, according to CCD (CCD, 2001: *unpublished*)

a) Poor postures leading to reports of pain in the neck, shoulder's and back.

b) Vibration leading to reports of driver postural stress and strain
c) Poor control location leading to reports of pain in driver's arms, wrists and hands
d) Long working hours leading to a build up of postural pain and stress

5.2 Analysis

The CCD study of the ergonomics of RTG cranes for the POF consisted of task analysis of driver activity, observation of driving postures and methods, discussions with drivers and managers, and hands on experience (CCD, 2001:*unpublished*).

A postural analysis was undertaken for the main ergonomic risks identified during the task analysis, namely:

- RTG driving, or moving the gantry around the container park and between container rows.
- Moving the cab and header unit into position.
- Attach/release the header unit and container in the container stack.
- Attach/release the header unit and container to the tug or haulage trailer (CCD, 2001: *unpublished*).

A four high and a five high type RTG were modelled for the analysis, within a two wide container bay with assorted 9′6′′ containers stacked in different combinations, to represent the worst case for driver vision (CCD, 2001:*unpublished*).

5.2.1 Postural analysis

A brief look at the postural analysis completed by CCD, will give insight into the postural positions of crane drivers, and possible areas at risk for Injury.

Certain working assumptions of driving posture were made before carrying out the analysis. These were based on observation and driver comments, and include:

1. The layouts for the cab design were identical for the four high and five high RTG's.
2. Drivers adjust their seats in order for the front of the seat to run in line with the rear structural floor bar in the cab. This allows the required downward

vision during driving and parking. Drivers sit further forwards on the seat cushion, rather than move the whole seat forward when needing to shift further forwards.

3. The seat was fixed straight ahead.
4. Small drivers require the footplates to be fully adjusted up.
5. Drivers have their right hand on the joystick and their left hand on the 'hoist' gantry control.
6. Seat armrests in the up position.
7. Seat belt was not worn.
8. No seat tilt.
9. No changes in seat adjustment between key driver tasks (CCD, 2001:*unpublished*).

5.2.2 Parking and driving

Postural analysis revealed a posture that allows for keeping the neck in an acceptable angle, with low ergonomic risk for the right shoulder, arm and hand. Although the legs were in neutral position enough to stabilise posture, RTG movement nonetheless increased stress on the drivers back and neck. This posture is held for a medium duration. The 25º of back flexion and 30º of neck rotation increased the ergonomic risk. There was also a low risk for the left shoulder and arm abduction. All postural angles are summarised in Table 6 below (CCD, 2001:*unpublished*).

<u>Table 6:</u> Postural analysis for parking and driving (CCD, 2001:*unpublished*).

	Forwards	Sideways	Rotation
Head	7º		
Neck	15º	8º	30º
Thorax	16º	5º	
Lumbar	10º	5º	10º
Pelvis	15º		
Total	63º	18º	40º

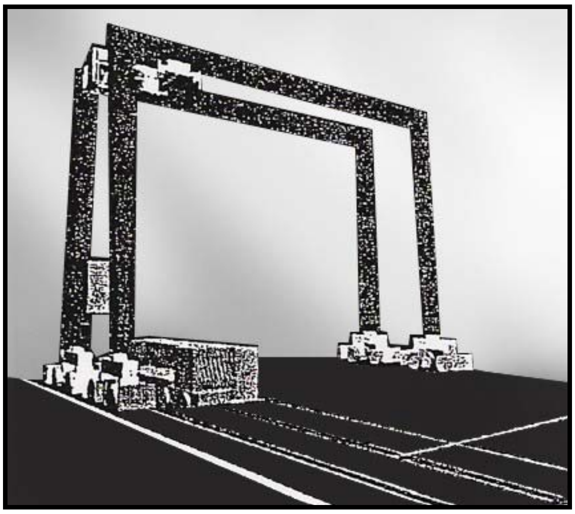


Figure 22: Parking and driving (CCD, 2001:*unpublished*)

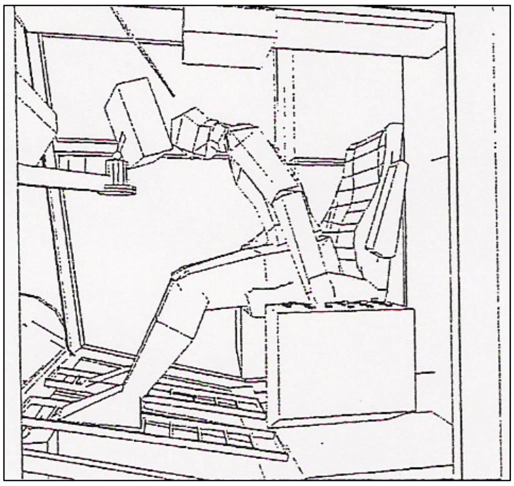


Figure 23: Position of the RTG driver (CCD, 2001:*unpublished*)

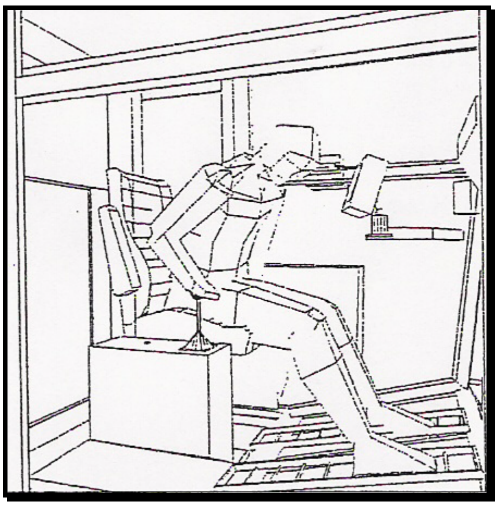


Figure 24: Position of the RTG driver (CCD, 2001:*unpublished*)

5.2.3 Moving the cab

This posture is held for a medium duration. Head and back in acceptable postural angles. Right shoulder, arm and hands in neutral, with left shoulder and upper arm in abduction. An acceptable posture is necessary to cope with stop/start jolting of the cab.

Table 7: Postural analysis for moving the cab and header unit into position five high type (CCD, 2001:*unpublished*).

	Forwards
Head	5º
Neck	5º
Thorax	15º
Lumbar	15º
Pelvis	5º
Total	40º

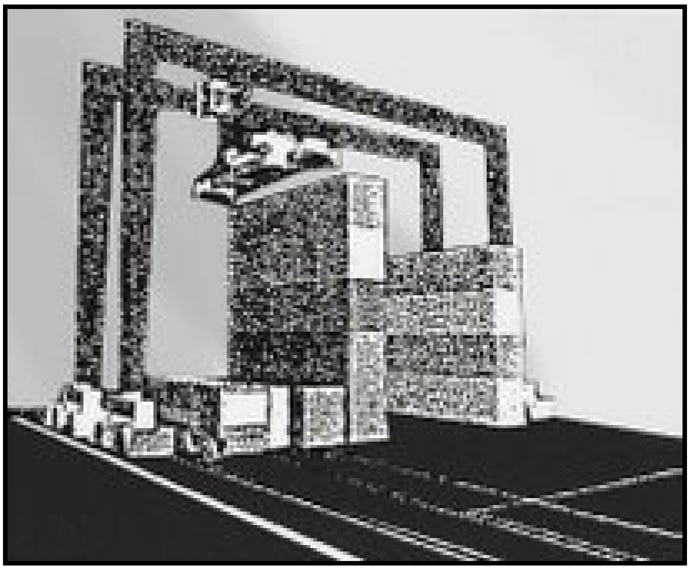


Figure 25: Moving the cab and header unit into position (CCD, 2001:*unpublished*)

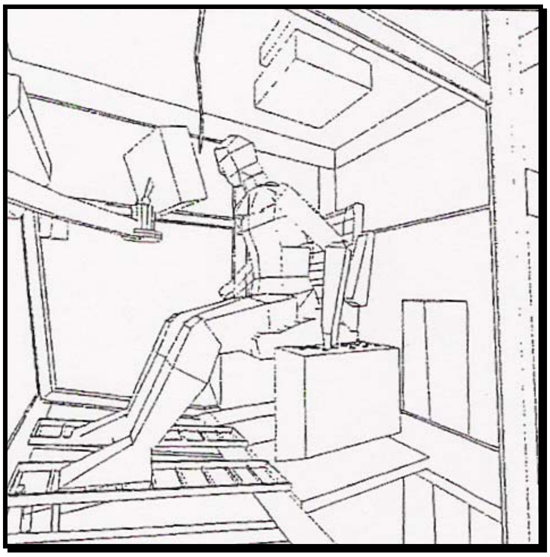


Figure 26: Position of the RTG driver (CCD, 2001:*unpublished*)

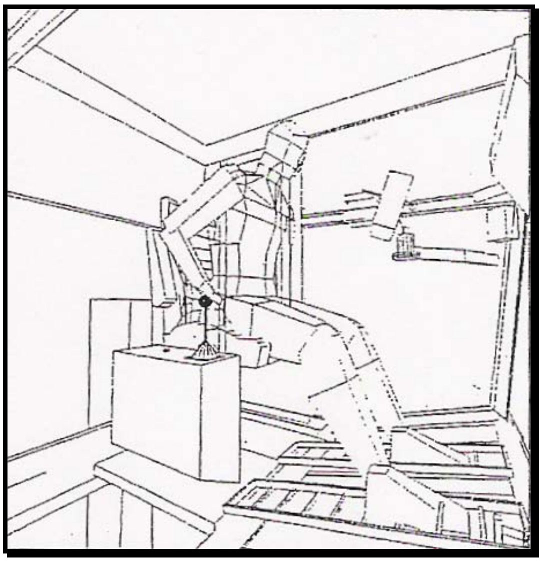


Figure 27: Position of the RTG driver (CCD, 2001:*unpublished*)

5.2.4 Manoeuvring the containers (1)

The first manoeuvre of the container to be assessed is attach/release container from ground five high type (worst case). This posture is held for medium to long duration. There is a high ergonomic risk due to the 85º flexion, and 28º of lumbar region flexion. The pelvis is flexed to 25º, which could cause a low risk of possible digestive problems.

The pressure on the ischial tuberosities is lessened due to the driver sliding forward on the seat to see the visual target. The pressure is now moved to the thigh, and causes high ergonomic risk of restricted blood flow and nerve compression. There is a high ergonomic risk from backward extension and abduction in shoulders, arms and hands. There is also no direct vision of target due to obstruction from the cab (CCD, 2001:*unpublished*).

Table 8: Postural analysis for attach/release container from ground five high type (CCD, 2001:*unpublished*)

	Forwards	Sideways	Rotation
Head	5º		
Neck	16º	5º	5º
Thorax	16º	4º	
Lumbar	28º	5º	10º
Pelvis	25º		10º
Total	85º	18º	25º

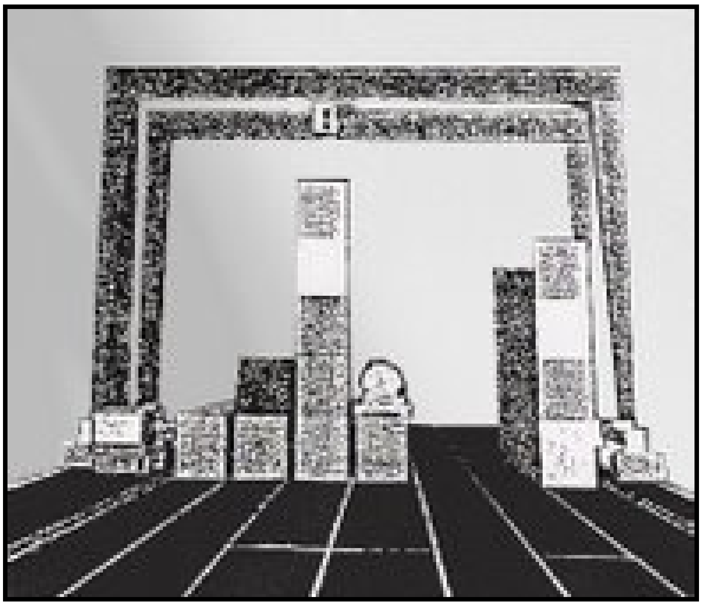


Figure 28: Attach/release container from the ground (CCD, 2001: *unpublished*)

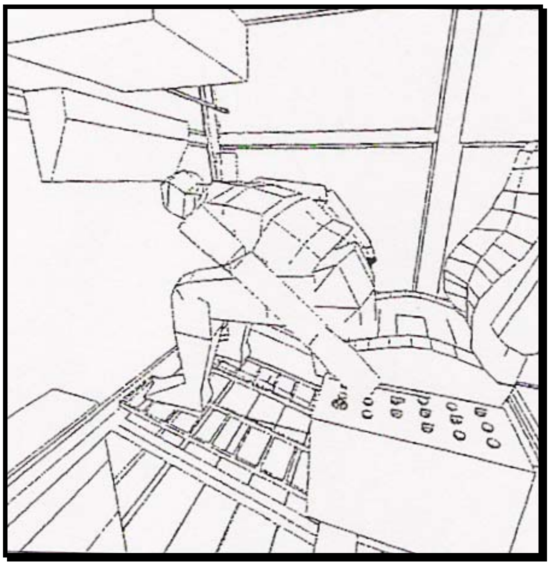


Figure 29: Position of the RTG driver (CCD, 2001: *unpublished*)

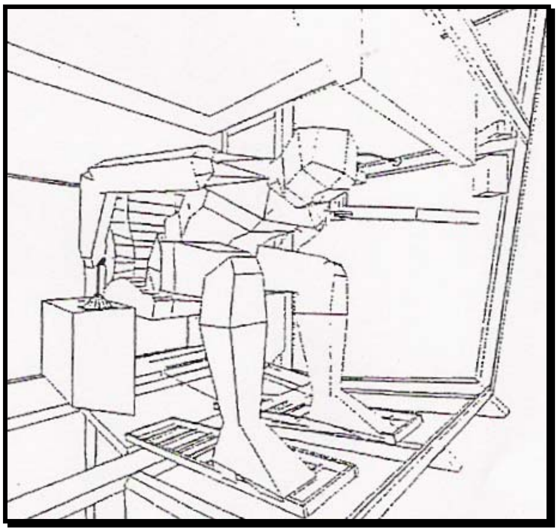


Figure 30: Position of the RTG driver (CCD, 2001: *unpublished*)

There is little difference in postural stress with the four high type, although postural angles are reduced slightly in all body areas.

5.2.5 Manoeuvring the container (2)

The second posture is involves attach/release the containers from haulage vehicles. This posture is held for a short period of time, and is a low ergonomic risk, although stress is taken in particularly the head and neck, due to the lean and rotation.

Table 9: Postural analysis for attach/release container from haulage vehicles (CCD, 2001: *unpublished*)

	Forwards	Sideways	Rotation
Head	18º		
Neck	10º	20º	15º
Thorax	8º		
Lumbar	4º		
Pelvis	5º		
Total	27º	20º	15º

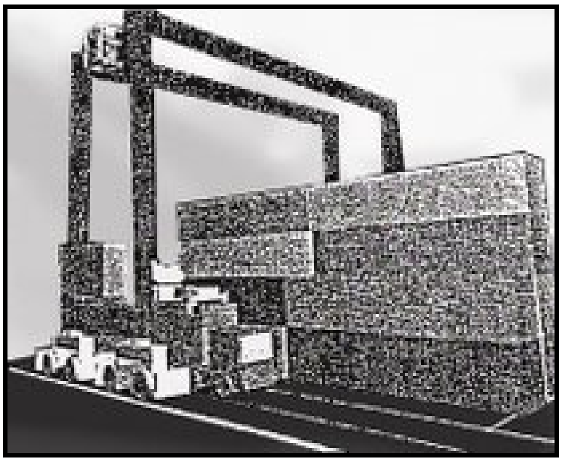


Figure 31: Attach/release container from haulage vehicles (CCD, 2001: *unpublished*)

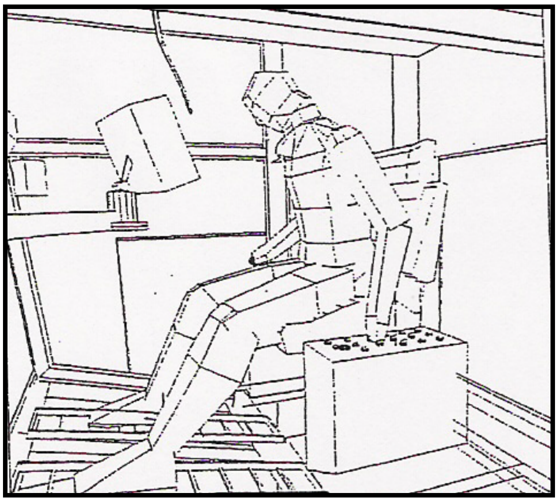


Figure 32: Position of the RTG driver (CCD, 2001: *unpublished*)

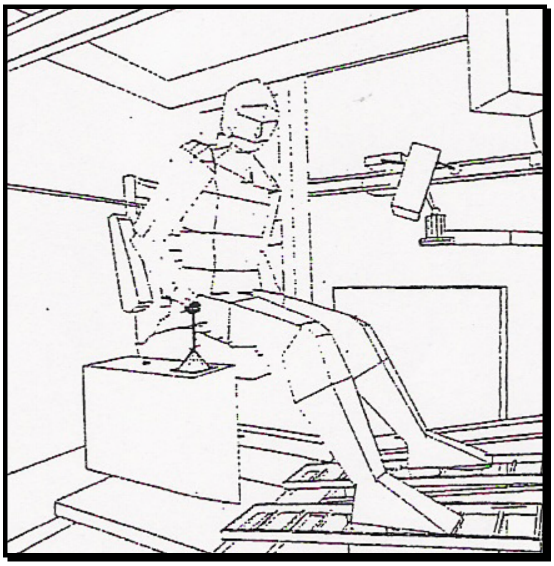


Figure 33: Position of the RTG driver (CCD, 2001: *unpublished*)

All RTG tasks pose at the least a low ergonomic risk for the driver. The pelvis and lumbar regions are at the most risk of stress in the attach-release container from ground (five high type) as depicted in Figure 29, 30. The average flexion of the lumbar spine was approximately 10º, except for the case mentioned above.

The RTG crane driver's tasks do not allow for neutral spine postural positions, and involve prolonged isometric muscle contractions for retaining the non-neutral positions. The assessment of specific dynamic and static muscles involved is important in determining what is necessary for prevention and pre-screening.

MUSCLE TESTING

Trunk muscle strength has also been indicated as a risk factor for LBP (O' Sullivan *et al.,* 2005; Bayramoglu *et al.,* 2001; Batt & Todd, 2000). Muscle testing forms an integral part of musculoskeletal evaluations (Shrier *et al.,* 2003). Various methods have been practised to assess trunk muscle strength, although few have been indicated as objective and quantitative. Accurate clinical measurements must be readily obtained to address problems of muscle strength. Measurements of muscle performance must be sensitive, precise, reliable and predictive of functional performance. Researchers must be careful to select a test that answers particular needs or questions (Shrier *et al.,* 2003).

As torque-measuring devices, isokinetic dynamometers are assumed to be precise and reliable if the instrument gauges a series of applied known torques accurately and repeatedly. Isokinetics have been used in testing and performance enhancement for over 30 years, demonstrating a wide use and numerous applications available for isokinetic testing and exercise (Brown, 2000:3; Delitto *et al.,* 1991).

The uses of an electromechanical dynamometer usually include collection of normative data, classification of muscle performance, and evaluation of relative efficiency and quantification of exercise regimes. Isolated isokinetic testing allows one to identify any pre existing weakness that may be present through documenting strength, power, and endurance. This makes it useful in pre-screening testing for deficits, and then progression to treatment. The tester also has control over test parameters such as ROM, speeds and translational stressors (Brown, 2000:7). Practically, isokinetics allows for accommodating resistance to muscular contraction and therefore has the ability to load the muscle effectively throughout it's ROM (Donatelli, 1991).

1. Isokinetics

1.1 Principles of Isokinetics

The principle of ‘constant angular devices’ have been used for many years. It was in 1967 that Hislop and Perrin first defined the concept of Isokinetics (Harter, 1995).
Isokinetic exercise and testing is based on a preset fixed speed principle, where the patient’s resistance is equal to the effort that they apply. As the limb accelerates to meet the present angular velocity, the isokinetic device produces a counterforce to maintain the preset speed. The lever arm can therefore measure the torque output throughout the range of movement. The procedures allow sensitive detection of muscle weakness specific to some part of the movement or to some functional contraction speed (Langrana & Lee, 1984).
Isokinetics is a dynamic muscle exercising and testing system, and exercises can be

performed concentrically (muscle shortens as it contracts) and eccentrically, where the muscle lengthens as it contracts (Prentice & Voight, 2001:154).

This form of measurement is unique in that it quantifies strength throughout the range of movement, and not just at the strongest point, as in manual testing. It is not affected by the speed of the movement, and accommodates for pain, fatigue, changes in length tension curve and biomechanical leverage of the muscle. This allows for safe and effective exercise and testing (Biodex Manual; Bell & Wenger, 1992; Donatelli, 1991).

Isokinetic testing is an effective way to attain objective measures that are valid, reliable and repeatable (Drouin *et al.,* 2004; Mandell *et al.,* 1993; Mostardi *et al.,* 1992; Keller *et al.,* 1999; Langrana *et al.,* 1984; Langrana & Lee, 1984; Lee *et al.,* 1999; Ganzit *et al.,* 1998; Almekinders & Oman, 1994). The set lever arm speed measuring muscular output is an efficient measure of assessment for peak torque, work and power.

The ability of a muscle to generate torque about a joint is a function of muscle moment arm, motor unit recruitment, and firing frequency (Prentice & Voight, 2001:153).

Various factors (torque values, compressive forces and translational forces) are affected by the testing speeds used in a protocol (Biodex Manual; Ellenbecker & Davies, 2000).

There is a 15º carry over effect on each side of the ROM. This is effective in rehabilitation where it allows for strengthening of a muscle within a non-exercised ROM (Biodex Manual).

1.2 Standardized Testing Protocol

A standardized testing protocol has been put forward to increase the reproducibility of results in Isokinetic testing. Fifteen parameters have been stated for performing an isokinetic evaluation (Prentice & Voight, 2001:155; Wilk & Arrigo, 1991; Biodex Manual).

1.2.1 Planes of motion

When testing musculature, the clinician needs to decide on a pattern that is specific to the motion and action that the patient performs during normal daily function. This is to approximate the normal length-tension relationship of the particular task. It is important to remember the biomechanics and planes of movement when isolating a joint.

1.2.2 Testing position/stabilization

Accurate data collection depends on adequate stabilisation of the joint, ensuring that there are no excessive movements above and below the joint that is being tested. The lack of adequate stabilisation can lead to higher torque values, therefore the straps on the system are used to eliminate this unwanted movement.

1.2.3 Axis of joint movement

The joint's axis of rotation needs to be aligned with that of the dynamometer. This allows for accurate measurements, as well as safe movement of the joint, and isolation of muscles groups. Poor biomechanics, due to unnatural movement of the joint, can lead to joint surface irritation and therefore inaccurate muscle function.

1.2.4 Client education

Research has found that there is significant difference in the first testing, to when the patient is familiar with the exercise/test (Keller *et al.,* 2001). Patient education can vastly change the amount of effort given by a patient, and their likelihood to produce their maximal effort. Educating patients verbally on what to expect, and what is expected, and through a practice session, can greatly improve and produce better results.

1.2.5 Active warm up

A general cardiovascular warm up of the joints being tested is recommended to increase the core temperature, and prepare the muscles for strenuous activity. A pre-speed warm up is also valuable for the patient to gain familiarity with the speed and practice giving sub-maximal and maximal effort.

1.2.6 Gravity compensation or Gravity Effect Torque (GET)

It is recommended that limb weight be factored into the data for elimination of the effect of gravity during testing. GET is the weight of the limb and the attachment, and is added to extension and subtracted from flexion to give an unbiased torque value.

1.2.7 Rest intervals

This can depend on how much time is available for testing. Different time intervals have been suggested, but the main concern is keeping this value consistent during testing. More rest time allows for better muscle recovery, which may need to be higher during strength testing but less during endurance testing (Parcell *et al.*, 2002).

1.2.8 Test collateral extremity first

Testing a pain free, uninvolved limb first can greatly reduce apprehension.

1.2.9 Verbal coaching

Verbal commands need to be encouraging and moderate in intensity. As this can have an effect on the patient’s response to testing, it is important to keep it consistent (Ambrosius *et al.*, 1994).

1.2.10 Visual feedback

The tester must remain consistent in the amount of knowledge, with regard to the results, that is presented during the testing protocol.

1.2.11 Angular velocities

The joint under evaluation, as well as the reason behind the testing, will decide which testing velocities are to be used. Traditionally, slower speeds have been used to assess strength, and faster speeds have been used to assess endurance. Smaller joints (wrist, ankle) are generally tested at slower speeds, while the knee and shoulder are tested at higher speeds. The principle of remaining consistent throughout the tests still hold true.

1.2.12 Test repetitions

At least three repetitions are needed to calculate data, but repetitions can depend on the test, as long as it is consistent throughout testing, and between tests. Increasing repetitions can result in more fatigue and discomfort, and therefore repetitions are kept low for slow speeds, and can be increased for higher speeds.

1.2.13 Calibration

This should be completed every 30 days, or before a test if necessary, for valid test results.

1.2.14 Isokinetic system level

The system should be set up in a stable area, as excessive movements of the dynamometer, or vibrations could be detected on the test results.

1.2.15 Use semi-hard end stop

The machine has a cushion value at the range of movement's end stop. As the limb moves through the ROM towards the end stop, the machine will begin to decelerate the limb. The cushion value can be adjusted, and it is recommended that a hard cushion be used for a smaller joint, as it minimises the machine-induced deceleration. The hard cushion can produce artificial spiking, which needs to be eliminated to avoid misinterpretation of the peak torque value.

1.3 Evidence of Isokinetic Testing

1.3.1 Reproducibility

There is a wide variety of trunk strength testing devices, and controversy exists regarding the reproducibility and validity of these measurements (Madsen, 1996). In clinical practise, assessment of muscular performance in the individual depends on the high reproducibility of the measurement. Previous studies have focused on the coefficient of correlation to express reproducibility, but this method is said to be misleading and in appropriate, as it measures the strength of a relation between two variables, not the agreement between them. The concept of critical differences has been developed by statisticians and recommended for the analysis of reproducibility. This has however, only been used in a few studies of muscle strength measurements (Madsen, 1996).

In a study on the Cybex 6000 dynamometer, large coefficients of variations and corresponding critical differences were found to be major limitation in the use of this testing, although it was suggested that trunk muscle strength measurements may be applicable when comparing groups of subjects. Confounding variables, such as confidence, motivation and mood may influence the reproducibility of measurements (Madsen, 1996).

1.3.2 Reliability

The Intraclass Correlation Coefficient (ICC) and Pearson Correlation Coefficient are commonly used when assessing the reliability of measurements. These statistical techniques are, however, insensitive to systematic changes in the subjects across trials due to a learning effect. The Standard Error of the Measurement (SEM) is another method for assessing reliability, and is well suited for interpreting individual scores. A study of 61 volunteers found relatively low reliability coefficients as well as large SEM's with extension-flexion ratios (FER) of the trunk based on peak torque to body weight (PT/BW) values. They demonstrated that a protocol using isokinetic dynamometry and resultant work measurements can be performed reliably in a sample of individuals during assessment of trunk musculature (Delitto *et al.,* 1991).

Conflicting results have been found for the reliability of the isokinetic trunk extensor test (Keller *et al.,* 2004; Dvir & Keating, 2003), and especially as a tool for employee selection (Dueker *et al.,* 1994). A learning effect and low reliability at higher angular velocities have been reported. Reliability of physical measurements can be evaluated by calculation of the ICC, the Coefficient of Variance (CV) and the Critical Difference (CD).

The ICC has been used frequently to assess reliability in isokinetic testing, but it is strongly influenced by the variation between subjects, and can therefore give a misleading high estimate of reliability.

A study by Keller *et al.,* (2004) chose to use the CD to describe reliability, due to its intimate association with within-subject variation. The study found reliability only to be acceptable for the isokinetic device at 60º/sec, as evaluated by CD. The authors found a learning effect between test one and test two, and suggest evaluation to be based on the second result (Keller *et al.,* 2004).

The CV may be quantifiable measure of reproducibility of repetitions. The CV is the standard deviation of the torque divided by the mean of the torque. The CV value, for research purposes, should nor exceed 10%. As the repetitions increase, so does the CV inflation and therefore is not as reliable for endurance testing. This value is said to represent the patient's level of consistency. This can be affected by effort, pain, understanding and apprehension (Prentice & Voight, 2001:157; Akebi *et al.,* 1998).

The Biodex System 3 Pro has been found to produce valid and reliable measurements for position, torque and velocity (Drouin *et al.,* 2004).

1.4 Factors Affecting Testing

1.4.1 Examiner

Examiners experience has been found to be important for consistent results, as well as feedback given during the test (Matheson *et al.,* 1992).

1.4.2 Testing conditions

Testing conditions, such as time of day, environment, and temperature could all play a role in the test results.

1.4.3 Stability of the patient

The patient is strapped in for isolation of specific joints, and to stabilise testing.

1.4.4 Between day reliability

Test results could differ from day to day, depending on the factors discussed above (Wyse *et al.,* 1994).

1.4.5 Gender

Males generally produce greater forces than females of the same age and activity level. It is therefore essential to keep the normalisation and comparisons specific to the population (Brown, 2000:11, Keller *et al.,* 1999). A study by Smidt *et al.,* (1983) showed that isometric, and trunk flexor/extensor strength differed between men and women. Men dominated in strength, but women tended to have higher endurance values.

1.4.6 Age

Although there is little consistency in the literature, it is widely agreed that torque, work or power decreases with increasing age. The main influential factor is more than likely the decrease in activity level with increased age (Brown, 2000:11; Akebi *et al.,* 1998).

1.4.7 Weight

Normalising a subject's test results to body weight individualizes performance to the specific size of the body (Hulens *et al.,* 2002). It has been showed to be one of the most important ways to interpret isokinetic performance (Davies, 1992).

1.4.8 Activity level

Athletes generally have more power and endurance, but this will also be specific to the type of sport (Brown, 2000: 12).

1.4.9 Presence of impairment

Impairments, or pain, could cause possible deficits when comparing the measures to normative data (Brown, 2000:12; Keller *et al.,* 1999). Rantanen and co workers (1995) found that the cardiovascular capacity of the patient was a limiting factor in isokinetic trunk muscle performance. HR was used, in that study, as a measure for estimating degree of effort.

1.4.10 Movement related factor

Force production of a joint is angle specific due to the biomechanics and length-tension relationships. Isokinetics provide accommodating resistance, which allows for maximal dynamic loading through the ROM, with each angle of the ROM having the capacity to develop different amounts of force production (Brown, 2000:12; Wilk & Arrigo, 1991; Biodex Manual).

Contractive and non-contractive tissue contributes to force production. Eccentric muscle actions therefore produce greater force than concentric actions which are only contractile. (Brown, 2000:12).

Modes of testing, although related, will differ according to isokinetic, isometric or constant load testing (Brown, 2000:13).

2. Isometrics

In isometrics, as the muscle contracts, there is no associated lengthening, or shortening. It is an effective method of rehabilitation, especially in the early, acute stages, as it is not affected by limited motion or painful arcs. There is a 20^{o} physiologic overflow with isometrics, which allows patients to work within painfree ranges, but still improve strength in the pain-effected areas (Prentice & Voight, 2001:154; Del Baso & Cafarelli, 2007). Maximal voluntary isometric contraction (MVIC) is a standard method of assessment for muscle strength (Meldrum *et al.,* 2007), and isometric trunk strength as been shown to decrease with cases of LBP (Descarreaux *et al.,* 2007; Descarreaux *et al.,* 2007). Isometrics have been found to produce valid and reliable strength data (Graves *et al.,* 1990), and can be used as an assessment of trunk fatigue (Corin *et al.,* 2005).

3. Stability

Pelvic or 'core' stability exercises have become increasingly popular in rehabilitation and management of low back conditions. It is a term that is widely used without being properly defined.

Firstly, the definition of a stable joint is a joint that moves through a normal range of motion when subjected to a normal physiological load. Therefore, an 'unstable' joint is one that is exposed to normal physiological loads, but moves through an abnormal, usually excessive range of movement This is usually due to the loss of functional competence of the soft tissues which are designed to restrain the movement.

The 'core' consists of the deep trunk muscles, including multifidus, Transverse abdominals (TrA) (Hodges, 1999; Hodges & Richardson, 1996; Barker *et al.,* 2006), internal obliques, pelvic floor, psoas and the diaphragm. The contribution and co-contraction of these muscles has been documented as contributing towards trunk stability (MacDonald *et al.,* 2006). Lumbar stiffness is also linked to, and increased by elevation of the intra-abdominal pressure (Hodges *et al.,* 2005).

The recent focus on stability exercises in prevention and rehabilitation usually focus on restoring dynamic stability of the spine to overcome low back dysfunction.
Dynamic instability is a result of insufficient strength or inappropriate recruitment of muscles that stabilise the spine (MacDonald *et al.,* 2006; Vezina & Hubley-Kozey, 2000; Hodges & Richardson, 1996; Barker *et al.,* 2006). Therefore, core stability exercises are designed to restore the ability of the neuromuscular system to control and protect the spine from injury or re-injury (Hodges, 2003; Gibbons & Comerford, 2001a). These exercises aim to control and co-ordinate spinal muscles to increase lumbar stiffness and therefore enhance stability to fulfil functional demands.

3.1 Clinical Instability

The term 'instability' has been used widely in the diagnosing and treatment of recurrent LBP. Panjabi (1992) developed a model incorporating three interdependent subsystems to explain the term 'instability.

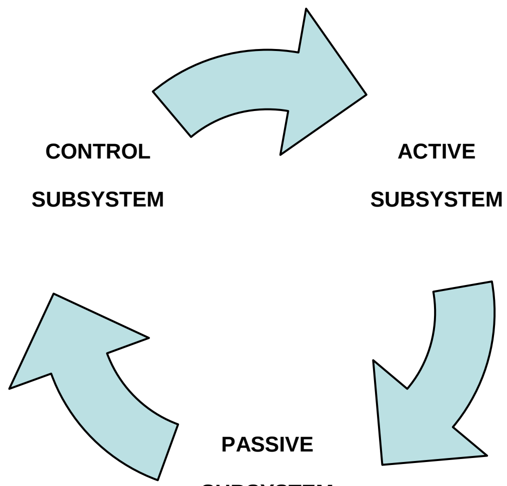


Figure 34: Three interdependent subsystems controlling spinal stability (Panjabi, 1992)

The passive subsystem consists of spinal ligaments and joint capsules that control movement of the spinal column. The deep local stability muscles make up the active subsystem, and these generate forces to stabilise the spine. The neural subsystem includes the components that control the muscles of the active subsystem. All three systems are responsible for spinal stability, and have the capability of compensating for one another.

Mitchell *et al.,* (2003) have divided Lumbopelvic mechanics into three distinct stability groups.

3.1.1 Intrapelvic stability

This is dependant on the TrA contracting with the posterior sacroiliac joint ligaments. The transverse abdominis' has its origin at the lower six ribs, the lip of the iliac crest, and the lateral inguinal ligament, and inserts onto the linea alba. It acts to flatten the abdominal wall and stabilize the linea alba (Kendall et al 2005:197). Problems in intrapelvic stability arise from two mechanisms:

3.1.1.1 Loss of active structure: Inhibition of transverse abdominis due to pain, pain inhibition due to joint inflammation, disruption of the origin of TrA due to a tear, surgery which affected the contracture or nerve supply to TrA fibres, or tearing of the pelvic floor during child birth.

3.1.1.2 Loss of passive structures: Sacroiliac joint laxity, or pelvic ligamtentous laxity due to hyper mobility, trauma or hormonal influence during pregnancy (Mitchell *et al.,* 2003).

3.1.2 Peripelvic stability

The initial component of stability, intrapelvic stability, is to ensure that the TrA, pelvic floor and sacroillac ligaments are able to maintain pelvic stability. Once this is achieved, the pelvis needs to be assessed in the way that it reacts with the rest of the body. Pelvisfemoral control, or the way the pelvis acts on the hip joint can be seen as excessive movement or 'dipping' of the pelvis on weight transfer, or one leg stance. The same can be assessed for lumbopelvic control or the pelvis movement with regard to the lumbar or thoracic spine. This could be affected by the ability of deep multifidus to contract to control the lumbar segments, as well as orientation of the spine on the pelvis by the superficial multifidus (Mitchell et al; 2003).

3.1.3 Functional stability

Functional stability is the ability to maintain intrapelvic and peripelvic stability in activities of daily living or in an occupational setting. The strength and activation patterns have to be in place, as well as the control of the pelvis in relation to femur and lumbar movements (Mitchell et al; 2003).

In line with Mitchell *et al.,* (2003) lumbopelvic mechanics, a concept of Sacroilliac (SI) joint stabilization has been developed by Pool-Goudzwaard *et al.,*(1998). This involves stabilisation of the SI joint for load transfer from the spine to the pelvis. This stabilisation can occur in two ways:

1. Form closure: Interlocking of the ridges and grooves on the joint surfaces
2. Force closure: Compressive forces of the structures surrounding the joint, such as the muscles, ligaments and tendons.

Muscle weakness in force closure can lead to negative load transfer, and therefore continuous strain on pelvic ligaments, leading to pain and discomfort.

Gibbons & Comerford (2001b) noted that although there is an overlap between strength and stability, the terms are not synonymous. Stability dysfunction is classified as the failure of a movement system under a low load. Strength dysfunction is identified by the failure of the movement system under a high load (Gibbons & Comerford, 2001b; Comerford & Mottram, 2001). It is possible to pass a strength test, and still fail a stability test.

4. Rehabilitation

Exercise as a therapeutic approach to prevention, treatment and management of LBP has become increasingly more popular in the past few years (Jones *et al.,* 2005; Drezner & Herring, 2001; Carpenter & Nelson, 1999; Cohen & Rainville, 2002), and has been especially indicated for subacute and CLBP sufferers (Faas, 1996)

A lack of mobility, endurance and strength of the trunk, and surrounding musculature, has been indicated as a risk factor for recurrent LBP (Jones *et al.,* 2005; Tollison & Kriegel, 1989:345). Reduced trunk strength, and physical fitness have been indicated as predictors for LBP (Batt & Todd, 2000; Bayramglu *et al.,* 2001). An increase in trunk muscle flexibility has been positively associated with work retention (Campello *et al.,* 2006). Trunk muscle fatigue, and associated postural adjustments, has also been linked to LBP (Allison & Henry, 2002). Specifically to this study, a possible relationship was found to exist between flexed spinal postures, reduced back muscle endurance, physical inactivity and LBP (O' Sullivan *et al.,* 2005).

Work absenteeism decreased among physically active patients, and in those patients who actively partook in a rehabilitation programme after suffering from LBP (Campello *et al.,* 2006; Taimela *et al.,* 2000; Torstensen *et al.,* 1998; Ljunggren *et al.,* 1997). Patients in an active rehabilitation programme experienced fewer reoccurrences of persistent pain (Taimela *et al.,* 2000; Hartigan *et al.,* 2000) as well as experienced an increased patient satisfaction (Ljunggren *et al.,* 1997). A study by Wittink *et al.,* (2002) found no association between aerobic activity and LBP intensity. CLBP patients are able to continue with exercises with no increase in pain (Hartigan *et al.,* 2000; Cohen & Rainville, 2002).

Although exercise have been suggested as the most effective treatment of LBP in recent years (Kaplansky, 2000:107), controversy still exists as to which exercises are beneficial (Faas, 1996). Evidence also suggests that exercise adherence plays a role, as better results have been associated with supervised exercise groups, rather than self exercise (Torstensen *et al.,* 1998).

Spinal stabilization exercise programmes have been found to be most effective in reducing pain, and improving function for patients with LBP (Goldby *et al.,* 2006; Hitt & Lie, 2006; Hodges, 2003).

CHAPTER THREE

METHODS AND PROCEDURES

OVERVIEW

A Cross sectional analytical epidemiological study design was used for this study. The subjects were recruited from the POF, UK. The project was requested and approved by the Port of Felixstowe's Human Resources, and Occupational Health departments. The project and participation was promoted by going directly into the mess rooms, and speaking directly to the RTG crane drivers about the aim of the project. Questionnaires were sent out to all current RTG crane drivers to accumulate information regarding history of symptoms, length of driving, activity level, previous jobs and other relevant information. Over 400 questionnaires were sent out, of which 108 were returned. Drivers had to indicate if they were willing to participate in the study. All testing was completed by trained rehabilitation specialists and was undertaken at the IPRS physiotherapy and rehabilitation unit at the POF's occupational health centre. The test battery was divided into two parts, with each part completed on a different day. This was done due to the lengthy and strenuous nature of the tests. All the subjects participating in the study were male, and employed by the POF.

SUBJECTS

The interested candidates that completed the questionnaire were contacted. There were a total of 81 subjects were contacted at the start of the study. These subjects were divided into two groups:

i. Experimental : Asymptomatic candidates with no documented back problems
ii. Control: Asymptomatic candidates with documented back problems

A total of 43 subjects (N=43), twenty-two experimental (n=22) and twenty-one control (n=21), participated in the study. Five candidates did not want to be tested, and the rest did not complete testing.

1. Exclusion Criteria

All subjects had completed the questionnaire. This information was then used to determine who should be excluded from the study. The following criteria served as further exclusion for the

control group. Firstly, those who were experiencing symptoms at the time of testing were excluded due to the strenuous nature of the testing protocol.
Secondly, those subjects who posed a high risk of further injury (for example, candidates with a history of disc hernia, severe sciatica or other red flag conditions), for ethical reasons, were excluded from testing.
And thirdly, subjects were excluded if they had any other conditions that could be aggravated with testing (e.g. cardiac condition, other musculoskeletal injuries).

All subjects needed to give consent to testing, and testing was done in their own times, outside of their work shifts, which also lead towards a lot of subjects being excluded or not completing the test protocol.

RESEARCH METHODS

1. Kinanthropometric Measurement

The following pieces of apparatus were used during the kinanthropometric measurements:

- EKS manual scale (for weight measurement)
- Aluminium anthropometer (for heights and breadths),
- Vulkan anatomical tape (for girths and lengths),
- Harpenden skinfold calliper (for skinfolds),
- 250mm Baseline Goniometer (for ROM and hamstring measurement).

All apparatus was checked and calibrated before being used for testing. All data was recorded in a resting state according to established procedures. It was taken by a trained Biokineticist in a way that would be practical, inexpensive and time efficient. All subjects were tested in shorts and T-shirts.

1.1 Age

The subjects age (in years and months) and their date of birth, were recorded.

1.2 Body Mass

The subject's weight was measured on a manual scale, and their weight recorded to the nearest kilogram.

1.3 Height

The height measurement of the subject's stature was recorded with an aluminium stadiometer. This was recorded with the subject standing in the Anatomical Zero (AZ) position. The subject was instructed to stand with their weight evenly distributed between the two feet, their shoulders square, sternum lifted, and to look straight ahead. The stature was recorded as the vertical distance of the vertex from the floor/base, and was rounded off to the nearest cm.

1.4 Skinfolds

A Harpenden skinfold caliper was used. The skinfold is taken using the thumb and index finger to raise a fold of skin and subcutaneous tissue at the desired site. The edge of the plates of the calliper is then applied to the fold one centimetre below the fingers, and the measurement is taken after the full pressure has been exerted, approximately two to four seconds after application. This value is taken to the nearest 0,2 mm. All skinfold measurements were taken on the right hand side, and taken according to the sites recommended by Harpenden Calipers (http://www.assist.co.uk/harpenden) and used previously by Durin *et al.,* (1997).

1.4.1 Biceps skinfold

The subject stands relaxed, with the arm hanging loosely. A vertical fold is then taken over the body of the bicep muscle, midway between the anterior auxiliary fold and the antecubital fossa.

1.4.2 Triceps skinfold

The subject stands relaxed, with the arm hanging loosely. A vertical fold is then taken over the posterior body of the triceps muscle, midway between the lateral projection of the acromion process of the scapula and the inferior olecranon process of the ulna.

1.4.3 Subscapular skinfold

The subject stands relaxed. A diagonal (45°) skinfold is taken 2cm from the inferior angle of the scapula in a direction that is obliquely downwards, and outwards.

1.4.4 Suprailiac skinfold

A diagonal (45º) skinfold measured above the crest of the illium along the imaginary line coming down from the anterior auxillary line, just above the hip bone and 2cm forward.

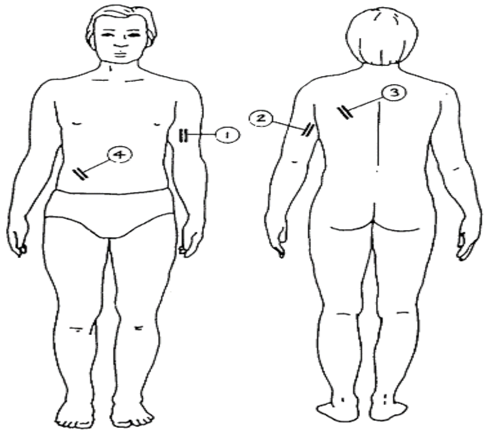


Figure 35: Skinfold measurements (Harpenden Calipers)

1.5 Girth Measurements

A non-stretchable anthropometric tape was used for all girth measurements. The tape was held snugly around the site, horizontally or at 90º to the length of the specific segment. All girth measurements were taken on the right hand side.

1.5.1 Relaxed arm girth (Tolerance limit =2mm)
The girth at the mid-acromimal-radial distance of the humerous, with the subject standing, and the arm relaxed, hanging loosely at the side.

1.5.2 Mid-thigh girth (Tolerance limit =2mm)
Subject is in a standing position, with feet shoulder width apart. A horizontal girth is taken midway between the inguinal crease and the proximal border of the patella.

1.5.3 Calf girth (Tolerance limit =2mm)
The subject is standing with feet shoulder width apart. The horizontal girth is taken at the level of the maximum circumference.

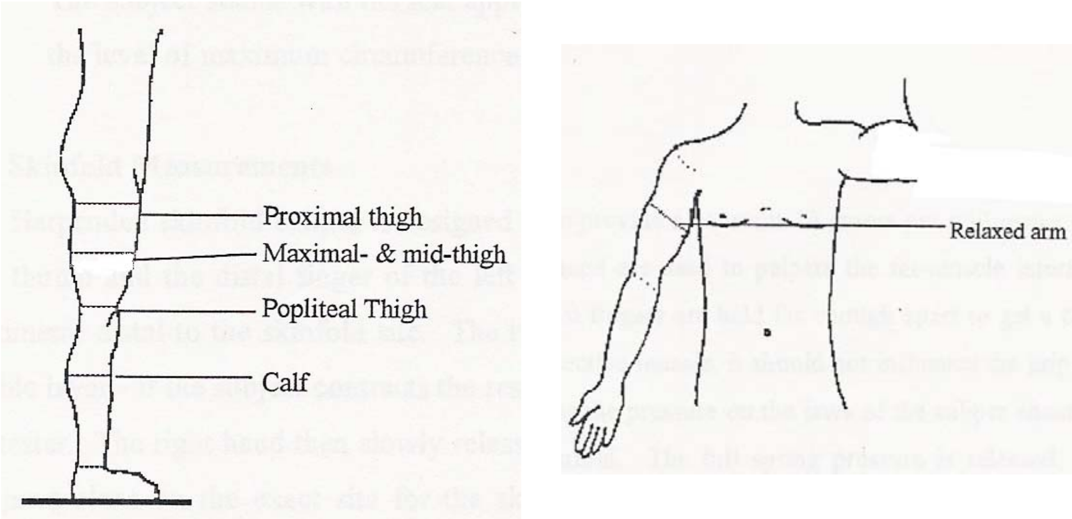


Figure 34: Girth measurements for the lower and upper limb

1.6 Circumference

1.6.1 Waist

The subject's waist circumference was measured from the umbilicus, at the narrowest point between the lower costal border and the top of the iliac crest, perpendicular to the long axis of the trunk.

1.6.2 Hip

The subjects' hip circumference was measured from the anterior superior iliac spine (ASIS).

1.7 Length Measurement

1.7.1 Distance from C7 to S1

A flexible non-stretchable anthropometric tape was used for the length measurement. The tape was pulled tight from each defined point, but did not compress the subcutaneous tissue. C7 and S1 were palpated, and the measurement was rounded off to the nearest one tenth of a centimetre.

2. Flexiblity

2.1 Hamstrings

Hamstring flexibility was measured using a 250mm Baseline Goniometer. The subject was asked to lie supine, and the examination table was considered the Zero Starting Position (ZSP). The extremity to be measured is in the ZSP, the fulcrum is positioned over the centre of the joint. The maximal ROM that the joint could go through without altering the ZSP, was recorded (in degrees). Each movement was repeated to ensure that the recording fell within the tolerance limit, and recorded to the nearest degree. The straight leg raise test was favoured over the sit and reach test, for hamstring and low back flexibility, in this study.

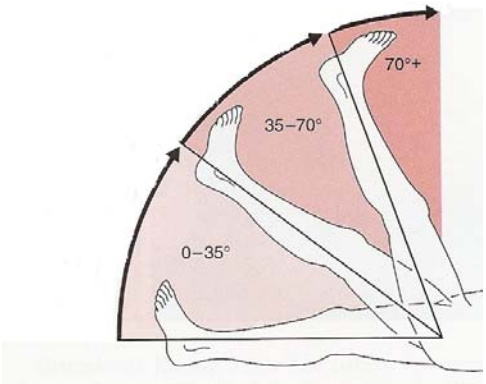


Figure 35: Test for hamstring flexibility/hip ROM

3. Stability

3.1 Assessment

Assessment of stability is essential in prevention, pre-screening and evaluating LBP. The trunk stability test (TST) level 1 has been used as an indicator of the subjects' ability to control the pelvis (Vezina & Hubley-Kozey; 2000**;** Richardson et al; 1999). There is evidence to support that TST level 1 recruits TrA and Erector Spinae co-activation (Vezina & Hubley-Kozey; 2000)

TST level 1 test

Subjects lay supine with hips and knees bent and feet flat on the exercise table and placed their fingertips on each side of the abdomen just above the pelvis and below the rib cage. They were instructed to tighten their abdominals, bring their navel up and in toward the spine, and hold this position until the end of the 4 second exercise. Once the spine was stabilized, subjects lifted their right foot off the exercise table until the thigh was vertical and the hip angle was 90 degrees. The left leg was then lifted to the same position. Legs were lowered one at a time to the starting position in the same order (Richardson et al; 1999).

The basic principles of this test were adopted for the testing of stability in this protocol. Testing procedures are discussed in the following chapter.

A Pressure Bio-feedback stabilizer was used to test activation of spinal stability muscles, and their ability to hold a spinal neutral position.

The test included a 10 minute standardised instruction and education on spinal neutral and contraction of TrA.

Each subject was instructed to lie supine with knees flexed, and was asked to extend one leg while maintaining spinal neutral (recorded as a pressure of 40 mmHg on the feedback system). Each subject was given 5 practise repetitions, and two tests were performed.

The ability to maintain a spinal neutral position for ten seconds was considered a pass, while the inability to hold a spinal neutral position for ten seconds was considered a fail.

Figure 36: Stability test using the Pressure Bio-feedback

4. Isokinetic

The isokinetic testing was preceded with a warm up of four minutes on the Biodex upper body cycle machine. The warm up also included two stretches:

1. Supine piriformis stretch
2. Cat curl stretch

Each of these stretches were repeated the stretch three times, and held for twenty seconds.

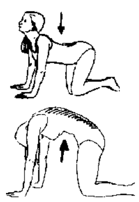
	**Supine Piriformis Stretch** Cross legs with involved leg on top. Gently pull opposite knee toward chest until a comfortable stretch is felt in the buttock/hip area.
	**Cat Curls** Breathe in as you let the spine curve inwards, and pull the shoulder blades together. Keep the knees directly under the hips. Breathe out as you curve your back upwards. Don't hold each position

Figure 37: Warm up stretches prior to the isokinetic and isometric tests

A standard explanation on isokinetic testing was given before each test. Each subject was allowed to complete 5 repetitions at 60º/second to familiarise themselves with the test.

The Biodex System 3 was used for all Isokinetic and isometric testing. This is based on a flat surface, and is regularly calibrated. All subjects were strapped into the chair to avoid any muscular compensation.

4.1 Extension / flexion Test

An Isokinetic/ Unilateral/ Lumbar extension/flexion (semi-standing) / Concentric/concentric test protocol was performed. Table 10 below indicates the repetitions performed at each speed. This is a recommended protocol (Brown, 2000:263) that is conducted in a comfortable, functional range of movement for the subject. Due to physiological overflow, it is suggested that it may not be necessary to test across a velocity spectrum. Traditionally, however, the five testing speeds below have been recommended (Brown, 2000:262).

Table 10: Isokinetic extension/flexion protocol

Speed	30 °/sec	60 °/sec	90 °/sec	120 °/sec	150 °/sec
Repetitions	5	5	5	5	20
Rest period	20 sec	20 sec	20 sec	20 sec	Recovered
Trial repetitions	1	1	1	1	1

A Negative fatigue value was often found at the last set (150°/sec) which indicated a need to retest to improve consistency.

5. ISOMETRIC

5.1 Extension Test

The same warm up for the isokinetic test was completed before the isometric test was performed. An Isometric/Unilateral/Lumbar (extension/flexion semi standing) protocol was completed. Table 11 below indicates the details of the test.

Table 11: Isometric protocol

Position (Away)	105°	120°	135°
Contraction time	30 sec	30 sec	30 sec
Relaxation time	20 sec	20 sec	20 sec

6. Questionaire

Each subject answered the questionnaire (Appendix A) before being considered for testing. The questionnaire focused on job, length of employment, previous employment, activity level, and previous history of injury. Symptomatic subjects were excluded from testing based on the questions in the questionnaire.

CALCULATIONS

1. Body Mass Index

Body Mass Index is also known as the Quetelet's Index, and it was recorded to one decimal point.

Weight

BMI = √ Height

2. Waist-to-Hip Ratio (WHR)

The WHR was calculated by dividing the circumference of the waist by the circumference of the hip.

$$\text{WHR} = \frac{\text{Waist circumference (cm)}}{\text{Hip circumference (cm)}}$$

3. Fat Percentage

The sum of the four skinfold values were used to determine body fat percentage from the Body data table used by the YMCA Manual (Golding *et al.,* 2001:171).

4. Average Performance Deficit (APD)

A Reference criterion of 100% was used as a norm for spinal muscles function.

Abbreviations: APR = Average Performance Ratio

PT = Peak Torque

BW = Body Weight

AP = Average Power

TW = Total Work

ER = Endurance Ratio (100 – Work fatigue)

Table 12: Parameters used for each isokinetic speed.

Speed °/s	30°/sec	60°/sec	90°/sec	120°/sec	150°/sec
Parameter	PT/BW	PT/BW	AP/BW	AP/BW	AP/BW
Parameter	TW/BW	TW/BW	TW/BW	TW/BW	TW/BW
Parameter					ER

$$APR = \frac{\text{sum of all parameters}}{11}$$

APD = 100% - APR

The APD was calculated for both lumbar flexion and extension.

5. Mean Torque Value

$$\text{Mean PT/BW} = \frac{\sum \text{PT/BW values at each speed}}{5}$$

6. Mean Flexion/extension Ratio

$$FER = \frac{\text{APR flexion}}{\text{APR extension}}$$

7. Angle Specific Torque Value

The same calculation was done for Mean PT/BW, and this was calculated for each angle.

CONCLUSION

A total of 43 subjects (N=43), twenty-two experimental (n=22) and twenty-one control (n=21), participated in the study. The subjects were measured according to various protocols as laid down by the Brussels Protocol and the American Academy of Orthopaedic Surgeons. All subjects completed the questionnaire, and were divided into control or experimental groups, depending on symptoms experienced. Kinanthropometric variables were measured, and these included heights, breadths, girths, circumferences, skinfolds, and lengths. The isokinetic and isometric tests were all completed on the Biodex System 3 in a semi-standing position. These tests included a warm up due to the strenuous nature of the testing.

The statistical analysis included calculation of correlations and significant differences, and these results will be discussed in the following chapter.

CHAPTER FOUR

RESULTS AND DISCUSSIONS

OVERVIEW

A total of 43 RTG crane drivers completed testing for this study. There were twenty two subjects in the experimental group, which were determined by an absence of documented symptoms or back problems. There were twenty one subjects in the control group, of which all were asymptomatic, but had a history of LBP. All subjects were males, and between the ages of 25 and 56 years old. All measurements and calculations are explained in Chapter Three.

The results of all the calculations and test values were analysed by the Centre for Statistical Services at the University of Stellenbosch. Analysis of variances was done on each of the measurement to determine possible significant differences in the mean values between the two groups. The level of significance was established at $p < 0.05$.

These univariate results served as a pre-analyis for highlighting possible measurements which could be used to predict whether a subject falls in the control or experimental group.

The ANOVAS showed trends for differences in the following measurements:

Age	p=0.07
APD Extension	p=0.06
FER	p=0.06
Extension (Extension (PT/BW 150))	p=0.04

All the p-values are close to the 5% cutoff of 0.05 indicating that the differences between the groups can only be seen as trends. It also already indcates that the variables would not perform well for classifying between the two groups.

All the other variables showed no significant differences.

The above mentioned variables were used in a discriminant analysis to determine whether they can be used in a multivariate setting to classify whether subjects fall in the control or experimental groups. Table 4.1 below summarises the classification results. From the table we see that there were 68% correct classifcations in the experimental group and 67% correct classification in the control group.

Table 13: Anova results

Class	Percent Correct	Exp p=.5000	Cont p=.5000
Rows: Observed classifications Columns: Predicted classifications Predictors: Age, APD Extension, FER, Extension(Extension(PT/BW 150))			
Exp	68.18182	15.00000	7.00000
Cont	66.66667	7.00000	14.00000
Total	67.44186	22.00000	21.00000

The following graphs depicts the ANOVA results.

INTRINSIC FACTORS

1. Gender

All of the 43 subjects that took part in the study were male. This is due to the minimal number of female RTG crane drivers. Due to the wide discrepencies seen for isokinetic values between male and female (Delitto *et al.*, 1991; Hoogendoorn *et al.*, 2000), combined with the nature of the occupation and available subjects, it was decided to only allow males to attend testing in this study.

2. Age

The mean age of the experimental group was 43 years old, and the control group was 38 years old. The mean age group is similar to that of other isokinetic studies done (Delitto *et al.*, 1991; Hoogendoorn *et al.*, 2000; Woodhouse *et al.*, 1993; Rantanen *et al.*, 1995; Keller *et al.*, 2001).

The experimental age group ranged between 26 and 56 years old, and the control group ranged between 25 and 51 years old. The wide range in ages is due to the varying age group for the RTG crane driver population.

Table 14: Comparison of mean ages in other isokinetic studies

	Gender			Range
	Both	Male	Female	
Current study				
Exp group		**43**		**26 – 56**
Control group		**38**		**25 - 51**
Rantanen *et al.*,(1995)			46.3	30 - 60
Keller *et al.*, (2004)	36			23 - 61
Langrana & Lee (1984)				18 - 40
Knapik *et al.* (1983)		26.1		20.6 – 32.4

Figure 38 below shows a trend for age to be higher in the experimental group. Although the statistics are not significant, it shows the trend for the average age of the experimental group to be older than the control group.

This is a valuable variable to note, as age has an important effect on trunk muscle strength, and in particular isokinetic strength (Langrana & Lee, 1984). Isokinetic strength tends to decrease with an increase in age (Langrana & Lee, 1984), and similar results have been found in this study, particularly in PT/BW with relation to body weight.

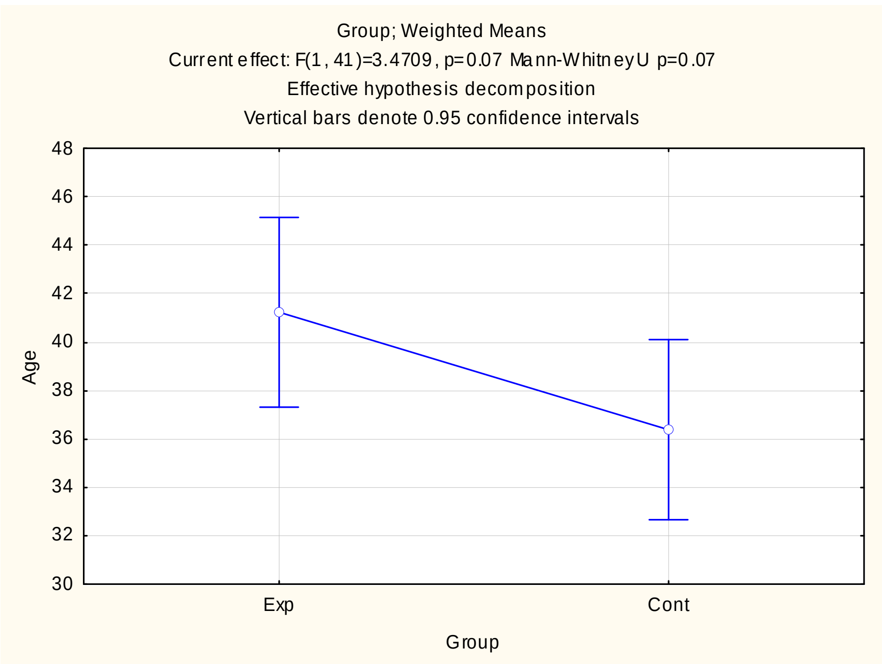


Figure 38: Age (years) for the current study

3. Experience

Table 15 below details the experience that the subjects had (mean years). This includes years at the POF, and as an RTG crane driver.

Table 15: Mean years of experience for the two groups

	POF	RTG
Control group	8.2	4.4
Experimental group	9.7	4.8

BODY COMPOSITION

Body composition refers to both fat and non-fat components of the body. Total body weight is composed of all these components, while lean body weight just refers to the weight composed of non fat or lean tissue, including ,muscles, tendons, bones and connective tissue. The body fat component is determined by the number and size of adipose tissues within the body (Arnheim & Prentice, 2000:132).

1. **Weight**

Table 16 below details the mean weight for the two groups, as well as the ranges. Although not statistically significant, the experimental group tended to have a higher mean value (Figure 39), as well as a wider range in weight. These values will have an effect on isokinetic and isometric test results, and especially those in relation to body weight (PT/BW).

Table 16: Comparison of mean weight between the two groups

	Mean (kg)	Range (kg)
Experimental group	86	67 – 128
Control group	81.9	65 - 106

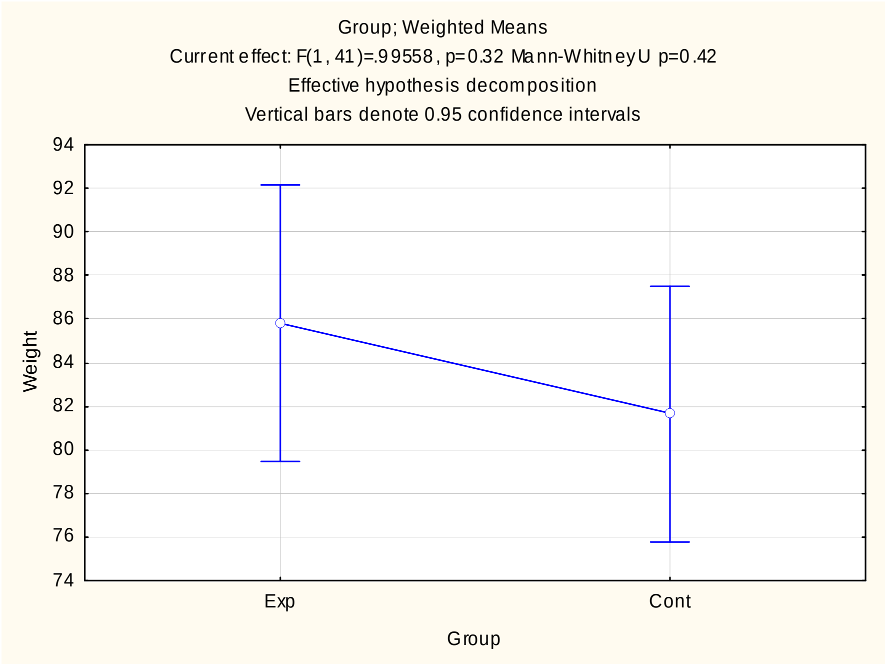


Figure 39: Weight values for the current study

2. Body Mass Index

The BMI is used to assess weight relative to height. BMI as an individual value is controversial (Nevill *et al.*, 2006) and has a relatively large standard error for estimating Body fat percentage, but can be used to classify obesity (Chen *et al.*, 2006), and has been found to be related to health problems associated with weight (Franklin *et al.*, 2000:63). It has been found to be a valuable variable in conjunction with other kinanthropometric values (Watts *et al.*, 2003; Duerenberg & Deurenberg-Yap, 2003; De Lorenzo *et al.*, 1998; Watts *et al.*, 2003). Classification for BMI can be seen in Table 17, and results for this study can be seen in Figure 40 below.

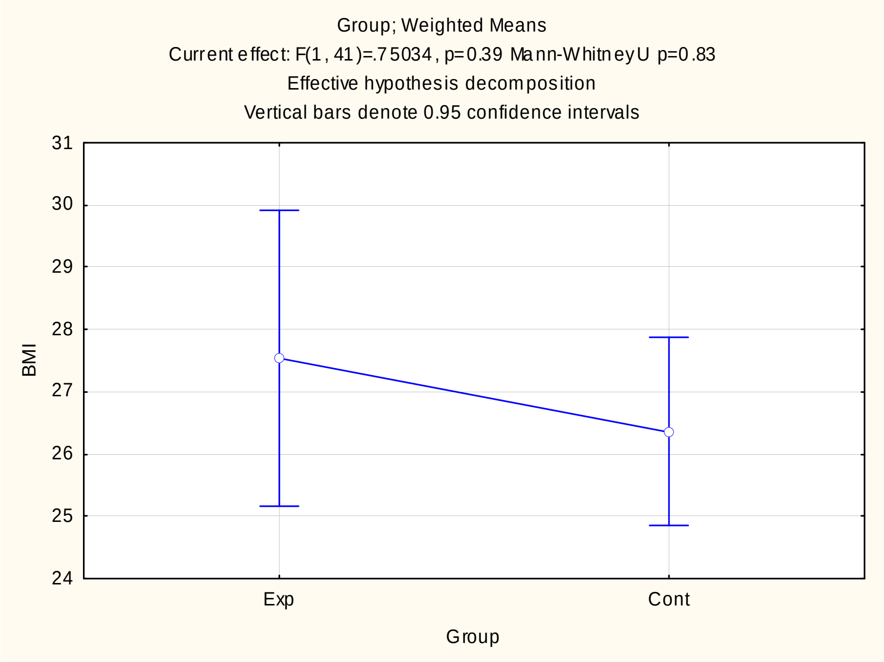


Figure 40: Body Mass Index for the current study

Table 17: Classification of disease risk based on BMI and waist circumference (Franklin *et al.*, 2000:64).

Disease risk relative to normal weight and waist circumference			
BMI kg/m²		Men, < 102 cm Women < 88cm	Men > 102cm Women > 88cm
Underweight	< 18.5	…	…
Normal	18.5 – 24.9	….	…
Overweight	25 – 29.9	Increased	High
Obesity Class I Class II Class III	 30 – 34.9 35 – 39.9 >40	 High Very High Extremely high	 Very high Very High Extremely high

3. Waist-to-Hip Ratio

WHR is recognized as an important predictor for health risk of obesity, as it provides information regarding the pattern of body fat distribution (Martin *et al.*, 2003) It is widely used in studies as a component of body composition (Elliott *et al.*, 2002; Beckham & Earnest, 2003; Oguma *et al.*, 2002; Schneider *et al.*, 2006). Individuals with increased abdominal fat are at risk for hypertension, type 2 diabetes, coronary artery disease and premature death. WHR has been used as a simple method to determine body fat pattern, and health risks increase with increased WHR, but can also vary for age and gender (Franklin *et al.*, 2000:63; Martin *et al.*, 2003).

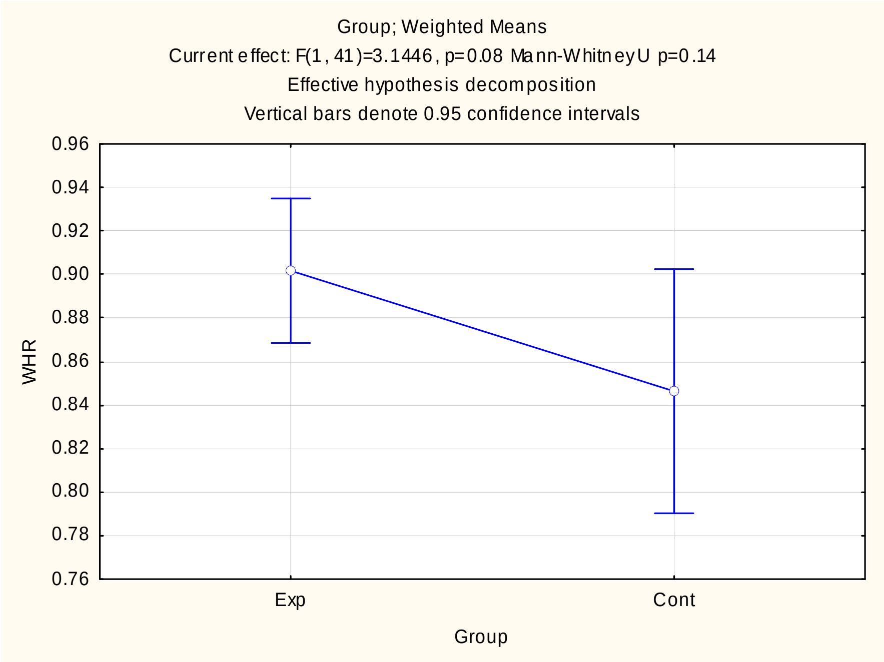


Figure 41: Results for Waist to Hip ratio

The values for WHR tended to be higher in the experimental group than the control group, although these values were not statistically significant (Figure 41).

4. Body Fat Percentage

There are several known methods to determine body composition, including hydrostatic weighing, measurement of electrical impedence (De Lorenzo *et al.*, 1998), dual energy x-ray absorption (DxA) in young adults (Franklin *et al.*, 2000:64; De Lorenzo *et al.*, 1998), or a hand held segmental body fat analyzer (Lintsi & Kaarma, 2003).

Skinfolds have been widely accepted as a practical, time efficient and non-invasive method of determining BF% (Franklin *et al.*, 2000:65; Deurenberg & Deurenberg-Yap, 2003; Eston *et al.*, 1995; De Lorenzo *et al.*, 1998, Chen *et al.*, 2006, Watts *et al.*, 2003; Reilly *et al.*, 1995; Brodie, 1988).

Skinfolds can be used as a valid and accurate measurement of BF% when measured by an experienced and trained Biokineticist. Variation between the left and right side are believed to be small (De Lorenzo *et al.*, 1998). There are various methods of measuring BF% using skinfolds (Deurenberg & Deurenberg-Yap, 2003; Eston *et al.*, 1995; De Lorenzo *et al.*, 1998, Chen *et al.*, 2006, Watts *et al.*, 2003; Slater *et al.*, 2006; Duthie *et al.*, 2006; Morris & Payne, 1996). The four skinfold site method was used (Golding *et al.*, 2001:171; Durin *et al.*, 1997), due to time constraints of the study.

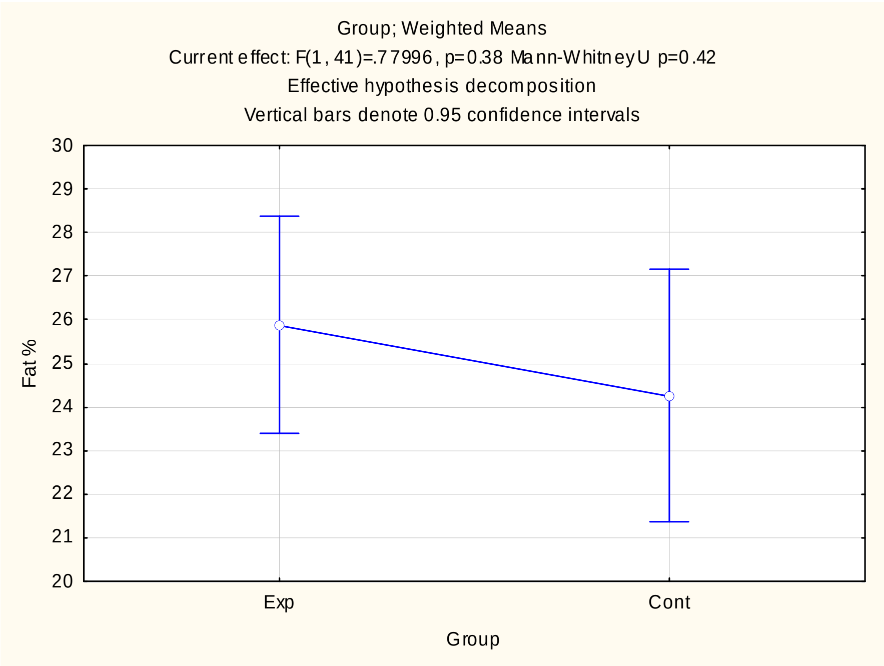


Figure 42: Fat % results for this study

No significant differences were found between the two groups for BF% (Figure 42), however, values seemed to be higher for the experimental group. This correlates well with the higher values in weight, BMI and WHR in the experimental group.

RANGE OF MOVEMENT

1. Hamstring Flexibility

The sit and reach (Franklin *et al.,* 2000: 87; Baltaci *et al.,* 2003), and straight leg raise test for hip flexion are used as a measure of hamstring flexibility. Hamstring and low back flexibility may aid in prevention of MS and low back injuries (Franklin *et al.,* 2000:87). The straight leg raise test was used for this study, and values were measured using a goniometer. This has been indicated to show normal length of hamstring muscles, as they permit flexion of the thigh toward the pelvis. An angle of approximately 80º from the horizontal landmark is considered normal (Kendall *et al.,* 2005:383; Magee, 2006:514, Askling *et al.*, 2006; Hopper *et al.,* 2005). The inability to reach 70º of hip flexion during a straight leg raise test, demonstrates tight hamstrings (Giza *et al.*, 2004).

Poor hamstring/hip flexibility along with poor abdominal strength or endurance contribute towards the development of low back dysfunction (Franklin *et al.*, 2000:87).

No significant difference was found between the two groups for hamstring flexibility, and the control group only tended to have a slightly higher mean value than the experimental group. However, both groups showed some tightness in their hamstrings.

Figure 43: Hamstring flexibility for the current study

STRENGTH MEASUREMENTS

LBP has been associated with weak lumbar and abdominal muscles (Batt & Todd, 2000; Tollison & Kriegel, 1989: 345; Biering-Sorensen; 1984; Luoto *et al.*, 1995; McGill, 2002:60), and the importance of strengthening the lumbar area to prevent and rehabilitate LBP has long been indicated (Graves *et al.*, 1990). Accurate and reliable testing is required for evaluating the effectiveness of training techniques, and for pre-screening those individuals who may be predisposed to lumbar problems originating from weak musculature (Graves *et al.*, 1990; Takala & Viikari-Juntura, 2000).

Isokinetics (Mandell *et al.*, 1993; Mostardi *et al.*, 1992; Keller *et al.*, 1999; Langrana *et al.*, 1984; Langrana & Lee, 1984; Lee *et al.*, 1999; Ganzit *et al.*, 1998; Dvir, 1997; Almekinders & Oman, 1994; Flory *et al.*, 1993; Wessel *et al.*, 1992), isometrics (Corin *et al.*, 2005; Graves *et al.*, 1990;

Battie *et al.*, 1989; Wessel *et al.*, 1992) and other techniques have been widely accepted as reliable and valid forms of trunk musculature evaluation (Akebi *et al.*, 1998). Isokinetic testing in pre-screening has been found to be useful in prevention of injuries (Gilliam & Lund, 2000).

1. Isometric Measurements

Isometric by definition means ‘same length’, and therefore explains the lack of associated muscle lengthening or shortening while the muscle contracts. Isometrics are commonly used as an effective method of muscle strengthening in the initial stages of rehabilitation (Prentice & Voight, 2001:153).

In evaluations of trunk muscle strength, isometrics have been used as a measure of force, and fatigue (the inability to maintain the isometric contraction). A study by Shrier *et al.*, (2003) found some relation between isometric trunk flexion force, fatigue and dynamic trunk flexion fatigue, although care needs to be taken when comparing these different physiological properties, as there was a lack of strong correlations. Studies have suggested that both isokinetic, isotonic and isometric testing modes are evaluating a similar phenomenon (Knapik *et al.*, 1983; Shrier *et al.*, 2003; Madsen, 1996; Mayer *et al.*, 1995; Akebi *et al.*, 1998) and may be adequate to predict a portion of strength between modes.

There were no significant differences found between the experimental and control group for isometric measurements, for all three tests (as seen in Figure 44 to 49). The possible reasons for lack of significant differences will be discussed in the chapter to follow.

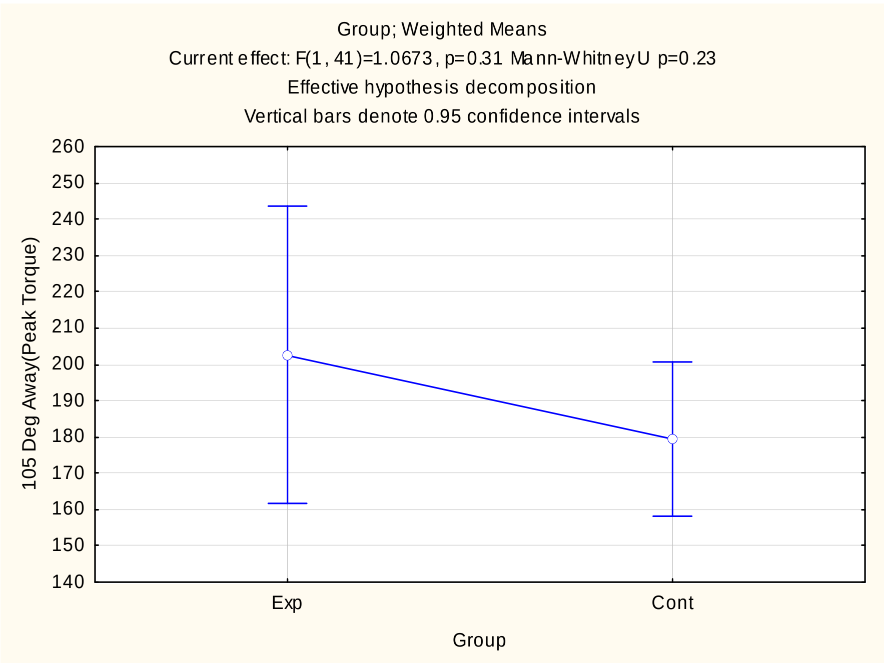


Figure 44: Peak isometric torque values for back extensors at 105°/sec

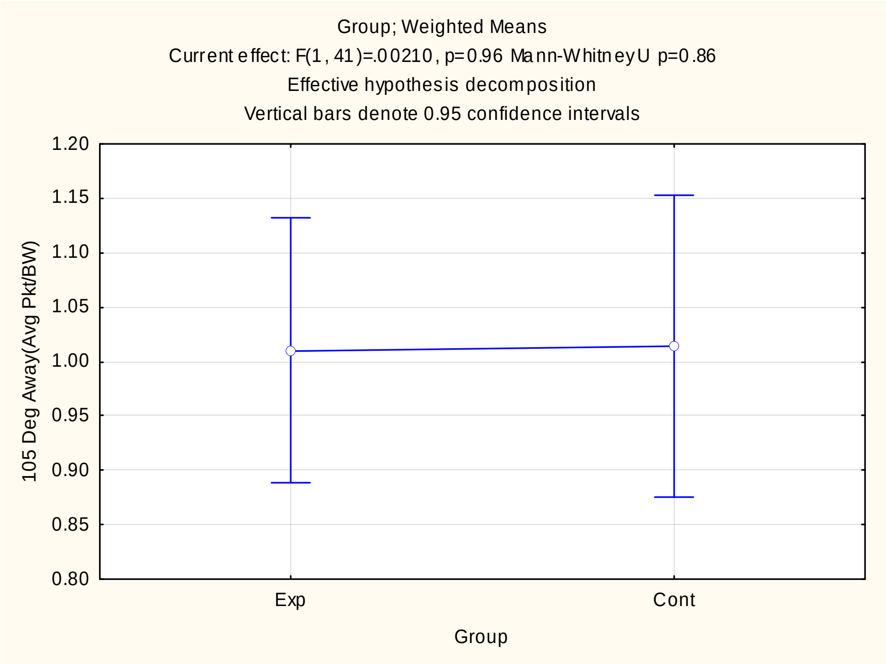


Figure 45: Average PT/BW values for isometric back extensor strength at a speed of 105°/sec

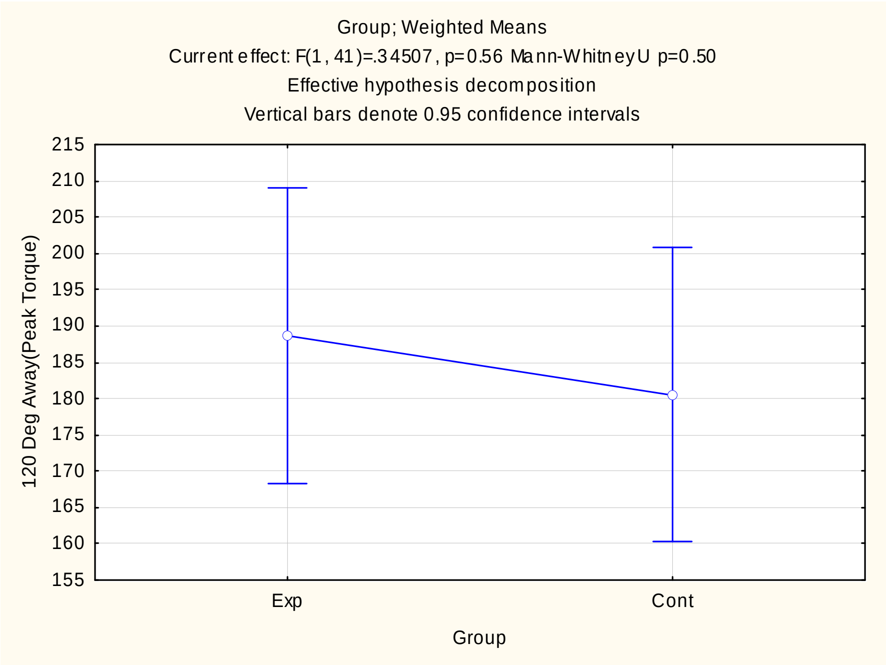


Figure 46: Peak isometric torque values for back extensors at 120°/sec

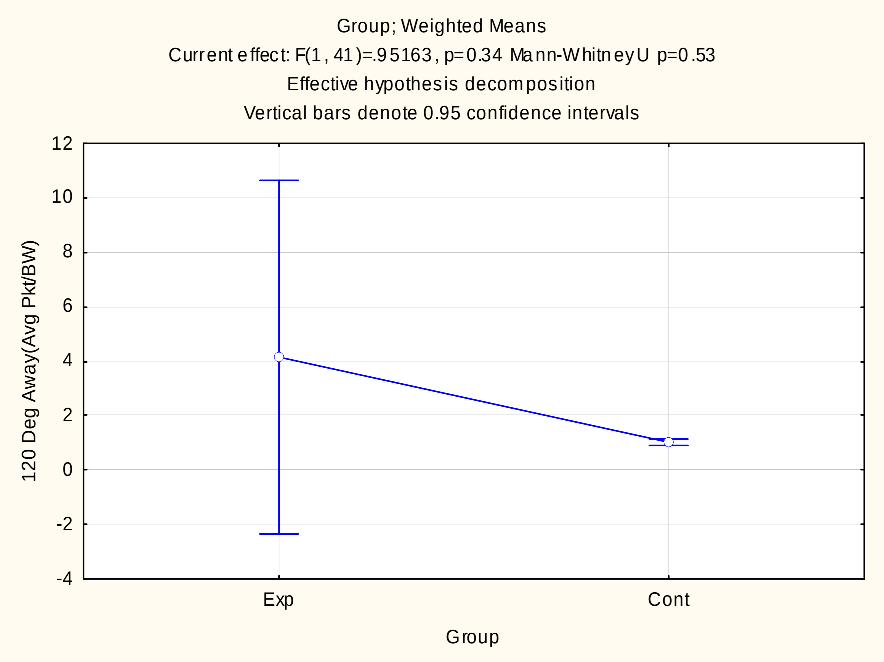


Figure 47: Average PT/BW values for isometric back extensor strength at a speed of 120º/sec

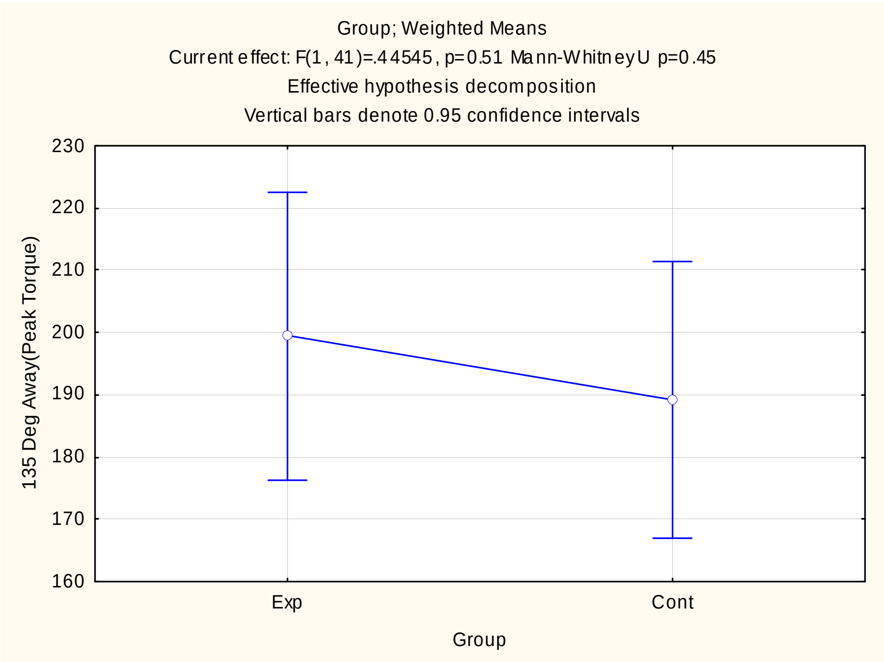


Figure 48: Peak isometric torque values for back extensors at 135º/sec

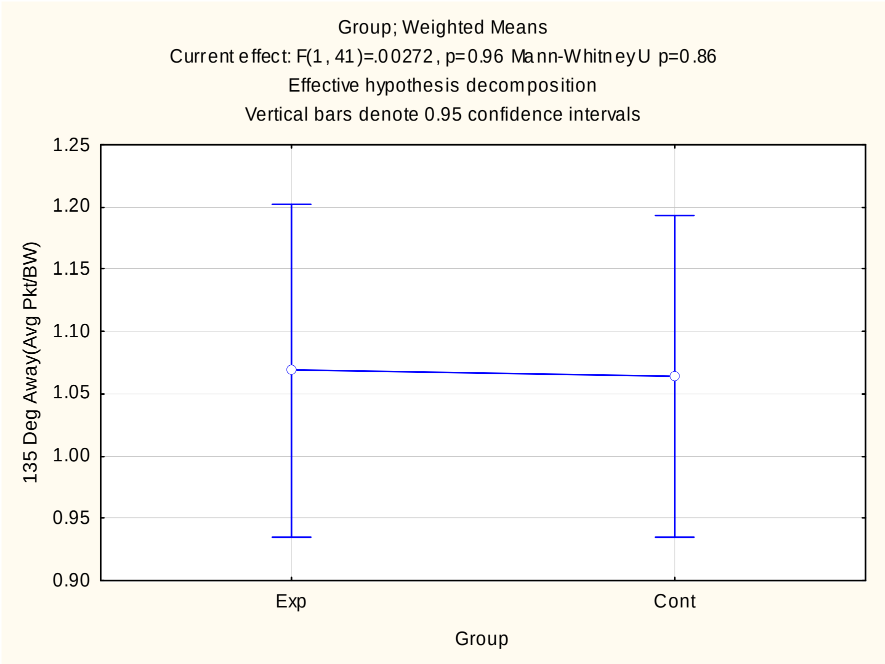


Figure 49: Average PT/BW values for isometric back extensor strength at a speed of 135º/sec

2. Isokinetic Measurements

Isokinetics or 'constant velocity' training and testing has been found to be an effective rehabilitation and pre-screening tool (Prentice & Voight, 2001:154; Brown, 2000:261). It has been shown in numerous previous studies to be a valid and reliable test (Karatas *et al.*, 2002; McClean & Conner, 1994; Dvir & Keating, 2001) and a possible indicator for future LBP (Bayramoglu *et al.*, 2001; Flory *et al.*, 1993; Takala & Viikari-Juntura, 2000; Lee *et al.*, 1999). Interpretation of isokinetic data is usually based on comparison between the injured and uninjured limb. However, for interpretation of the spine, there is no reference limb for bilateral comparison. Therefore, spinal data for interpretation should include APD, muscle performance index and normative data for PT/BW (Brown, 2000:264).

2.1 Average Performance Deficit

This method is practical and accurate, and involves only four repetitions at a test speed with a 20 second rest interval. It is based on 100% as the reference criterion for normal spinal muscle function, and is found to have high levels of intra- and interrater reliability (Brown, 2000:265; Timm 1995).

It does, however, require a testing protocol of 5 different speeds (30, 60, 90, 120 and 150 º/sec) and the method needs to be implemented to each movement (flexion, extension) independently (Brown, 2000:265).

Although there was no statistically significant difference between the experimental and the control group for APD, APD Extension showed (Figure 50) a higher trend in the experimental group (p=0.06).

APD was observed to be higher in the expieremental than the control group (Figure 50). This suggests that the average power, or the power needed to maintain or repetitively produce a force, was higher in those previuosly asymptomatic patients. This is important to note in an occupation such as RTG crane drivers, due to the demand to maintain a static (forward flexed) posture, and repetetively produce force (albeit endurance) during their working shift. This is a useful value to determine in the pre-screening protocol, bearing in mind that trends showed higher for those who are asymptomatic.

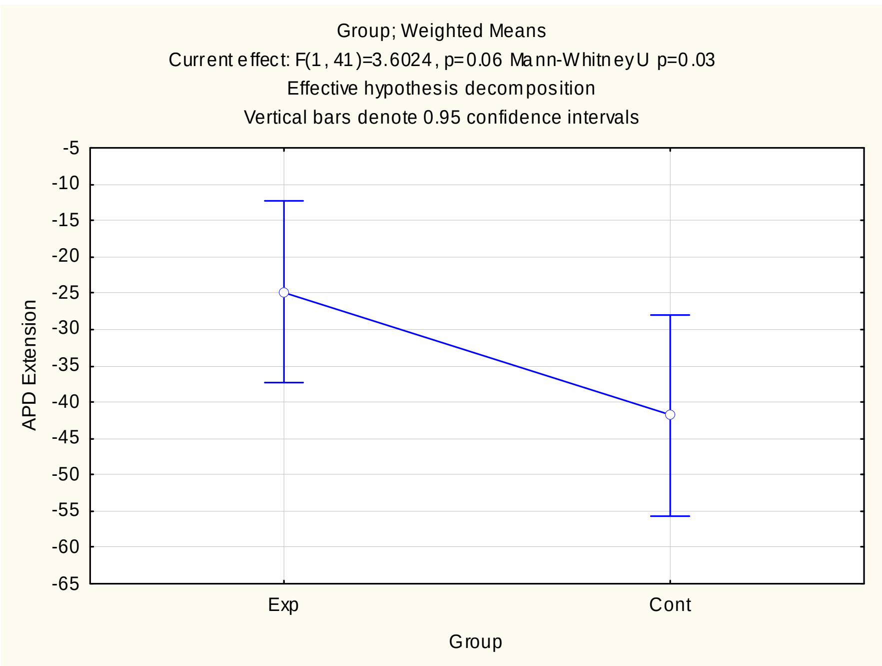


Figure 50: Average Performance Deficit values in extension

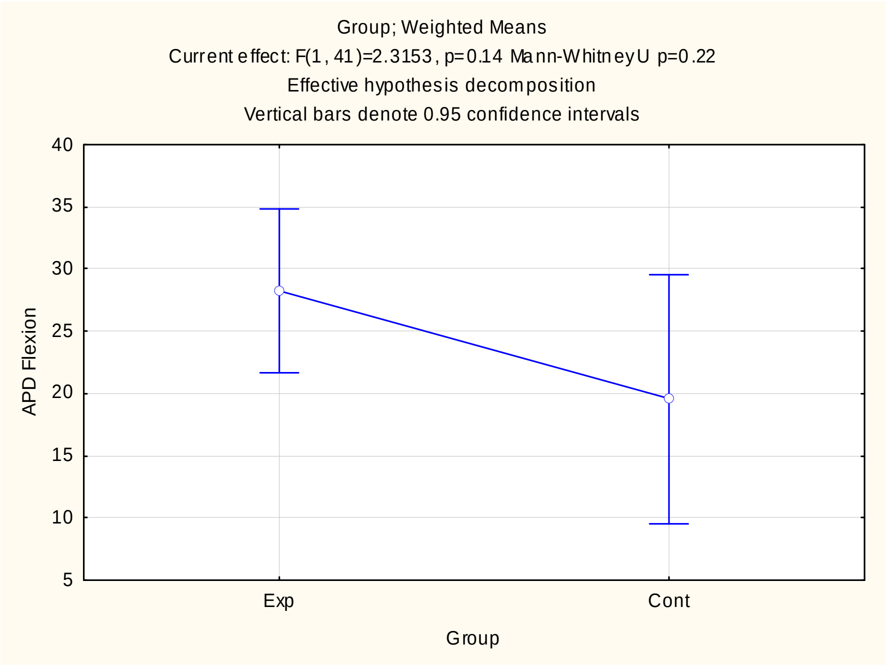


Figure 51: Average Performance Deficit values in flexion

2.2 Flexion to Extension Ratio

In patients with LBP, the loss of extensor strength tends to be greater than that of flexor strength (Mayer *et al.*, 1989; McNeill *et al.*, 1980). The normal extensor to flexor ratio is 1.2 to 1.5, and has been documented at 1.0 for patients with CLBP (McNeill *et al.*, 1980).

The ratio of flexion versus extension (FER) was observed for the experimental and control group. The FER also showed a trend of being higher for the experimental group (p=0.06). This has led to the belief that pre-screening may need to move away from abdominal strength, but rather focus on ratio of flexor to extensor muscle strength. The current study was found to have similiar values to the Biodex manual and higher values that other studies (Delitto *et al.*, 1991), possibly due to the nature of the workers occupation.

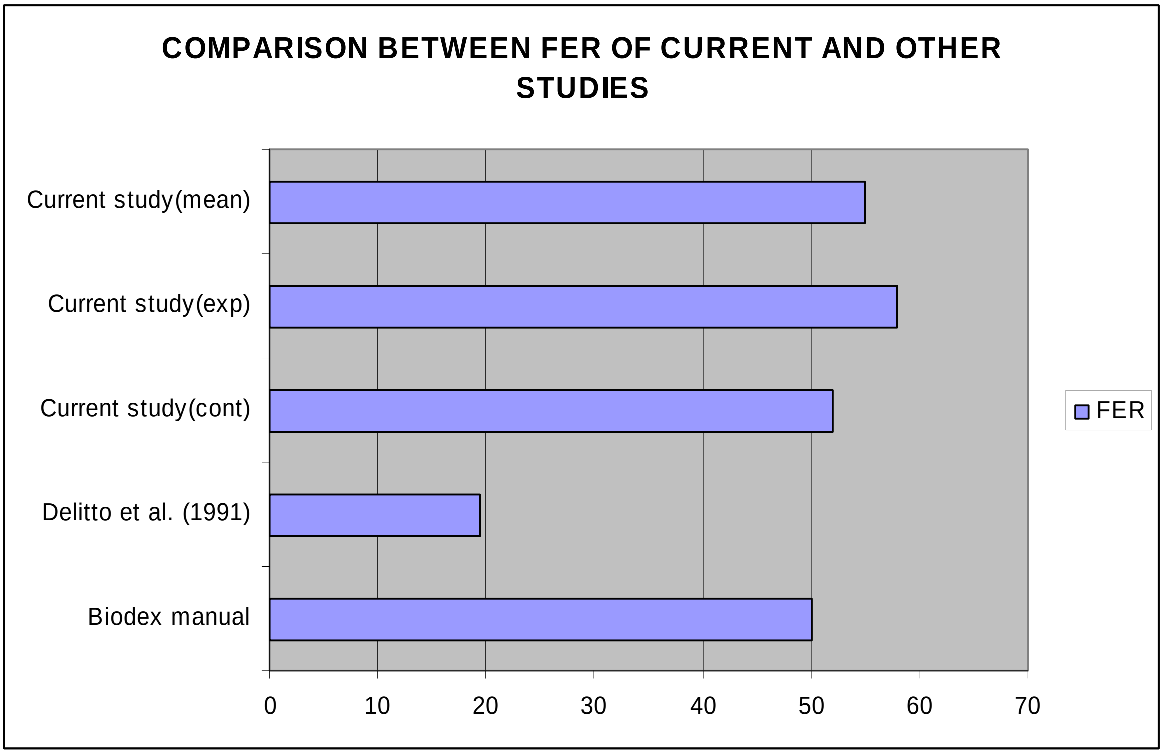


Figure 52: Comparison between Flexion to extension compared to other studies

Figure 53 below shows the results for the FER for the current study.

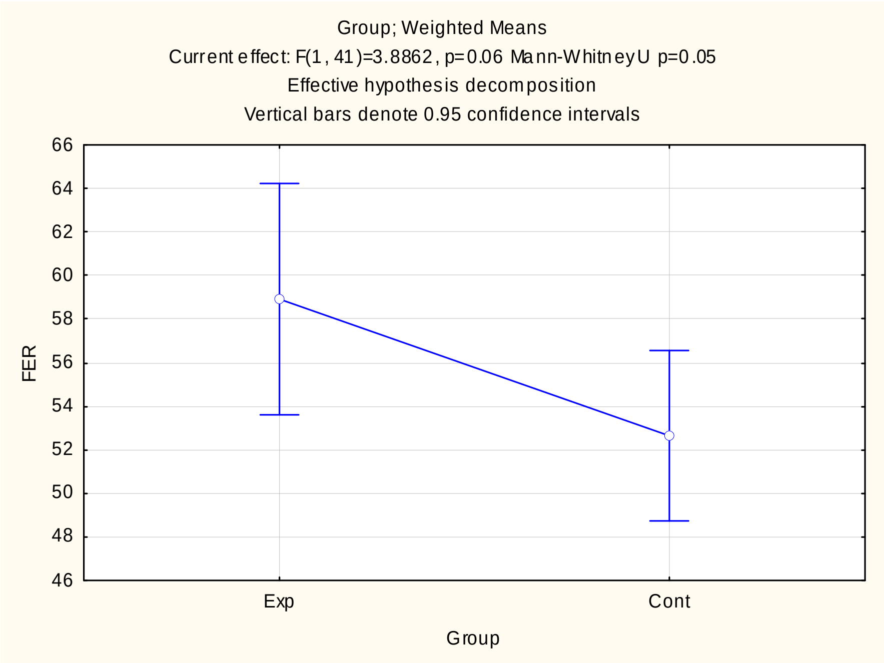


Figure 53: Flexion to Extension Ratio values for the current study.

2.3 Mean Torque Values

The normative data of PT/BW has found the following significant differences:

1. Differences in gender, as males were found to have higher values than females
2. Differences in test motions with extension > flexion
3. Differences between accuracy of the isokinetic parameters, with PT/BW being the single most important measurement of spinal isokinetic muscle function (Brown, 2000:265).

In the current study, no significant differences were found in mean PT/BW between the experimental and control group, as seen in Figure 55.

Figure 54.shows that the current study produced similar results to those found in the normative data (Brown, 2000:265). The extension values seem to be higher in the current study, possibly due to the ergonomic situation of the drivers, and the fact that the current subjects are a specific occupational group.

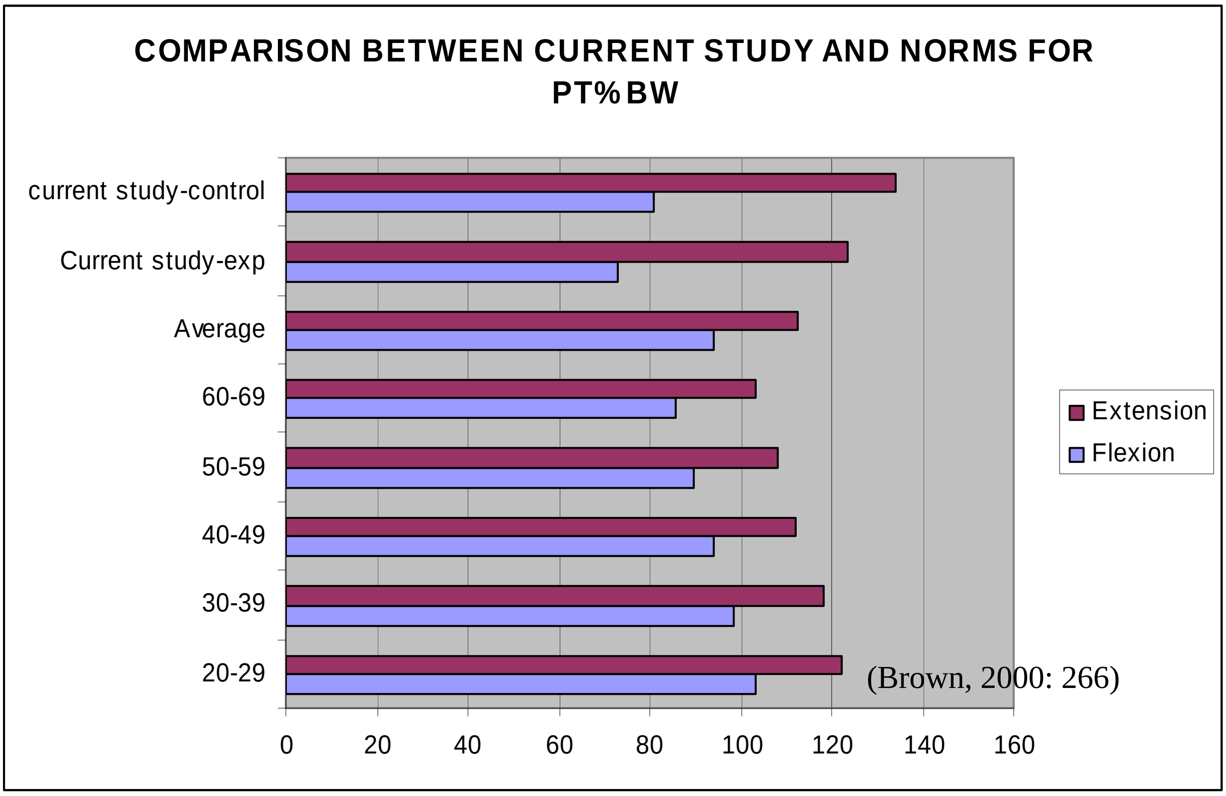


Figure 54: Comparison of PW/BW for the current study compared to normative data.

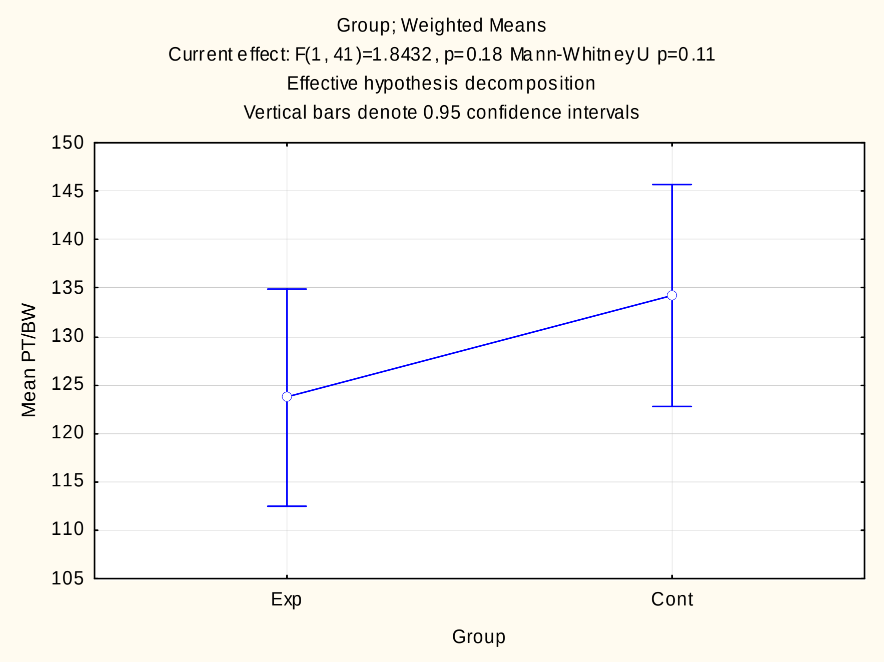


Figure 55: The mean PT/BW isokinetic values for the current study

Comparison of normative data between speeds (30º/sec;60º/sec;90º/sec;120º/sec;150º/sec) shows no significant differences in overall performance between single speed and multiple speed test protocols (Brown, 2000:267). This suggests that a subject may be tested at one of the above speeds, for an accurate measurement of spinal function.

The following graph shows a comparison between PT/BW values for the current study compared to studies at the same two speeds (60º/sec and 120º/sec). The current study showed similar values for flexion, and slightly lower values in extension compared to Biodex Manual's normative data.

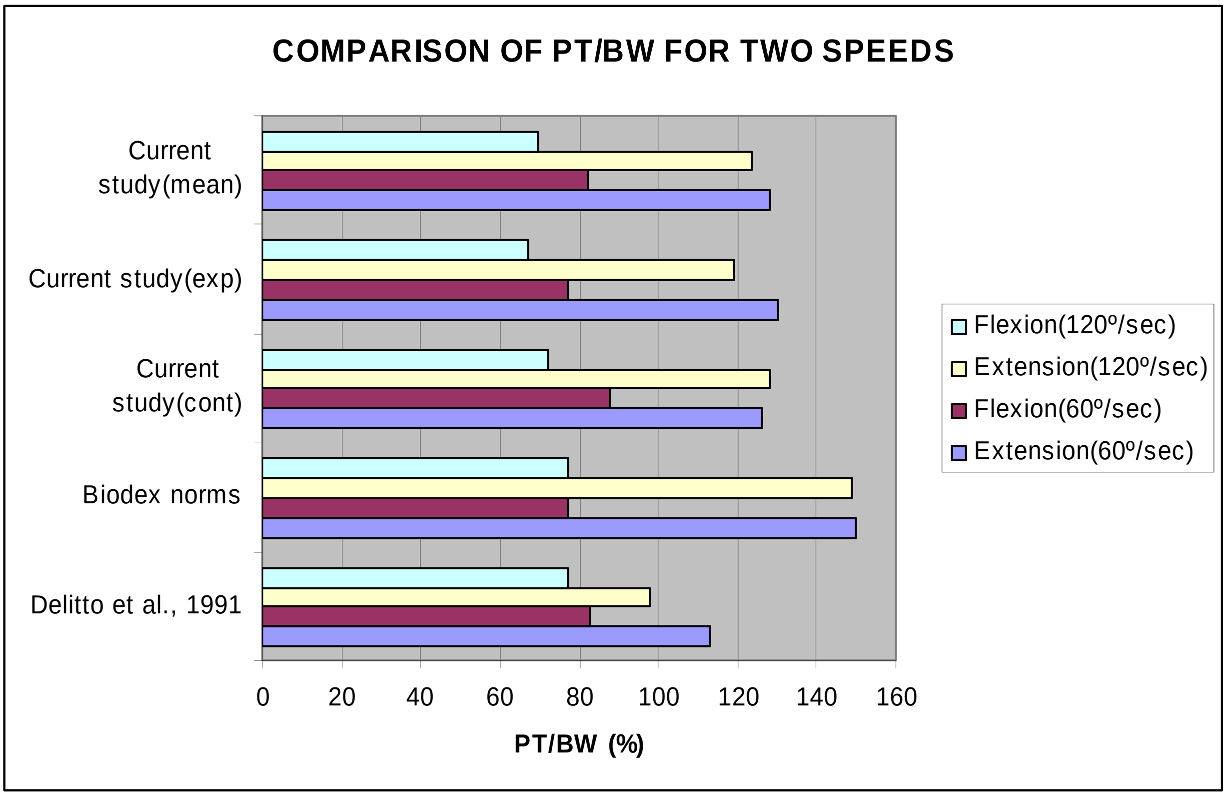


Figure 56: Comparison of PT/BW for two speeds in different isokinetic lumbar tests.

2.4 Torque for Extension

The graphs below show the values for the current study for PT/BW in extension for the 5 different isokinetic speeds. No statistically significant differences were found between the two groups.

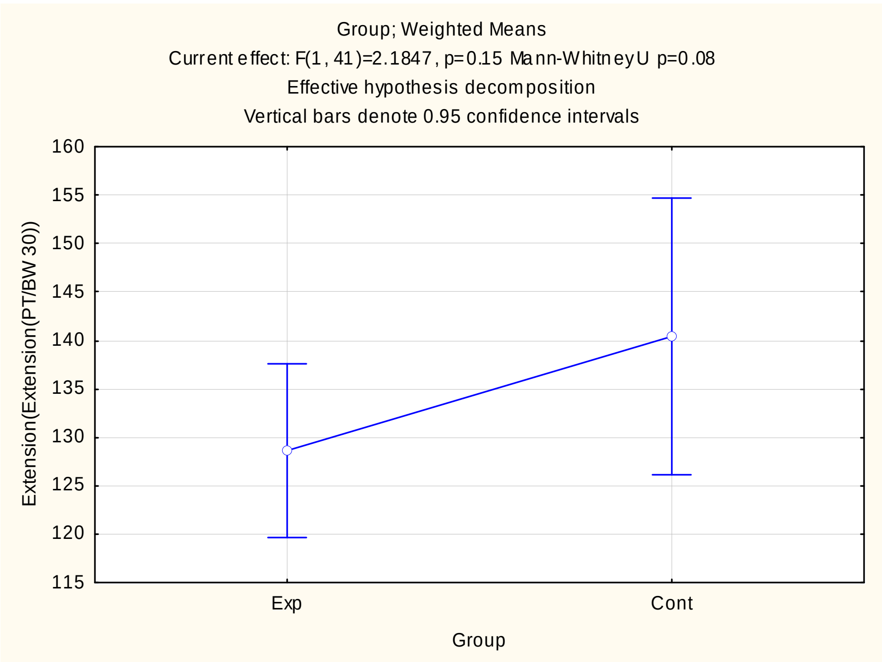


Figure 57: PT/BW isokinetic values for back extension at 30º/sec

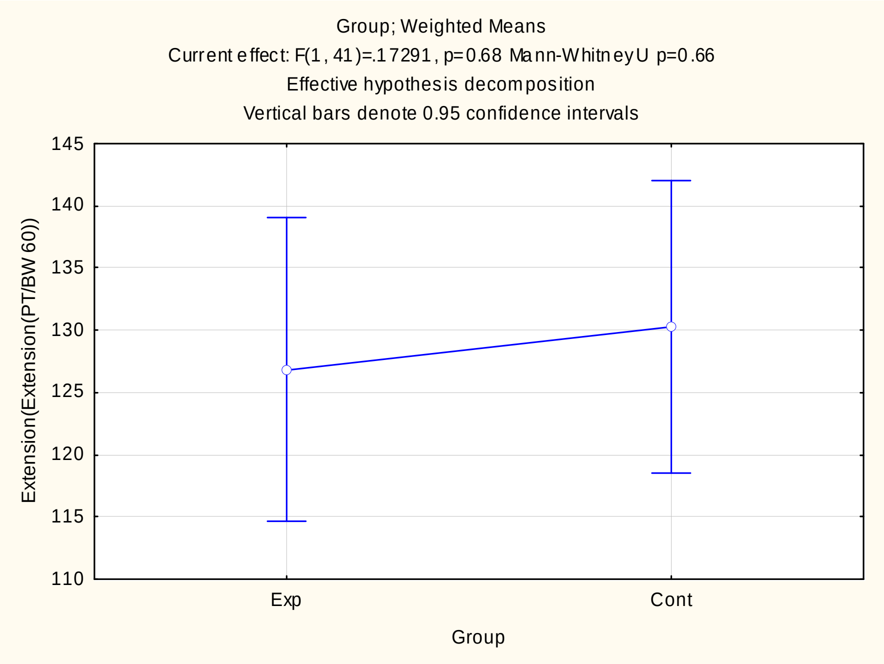


Figure 58: PT/BW isokinetic values for back extension at 60º/sec

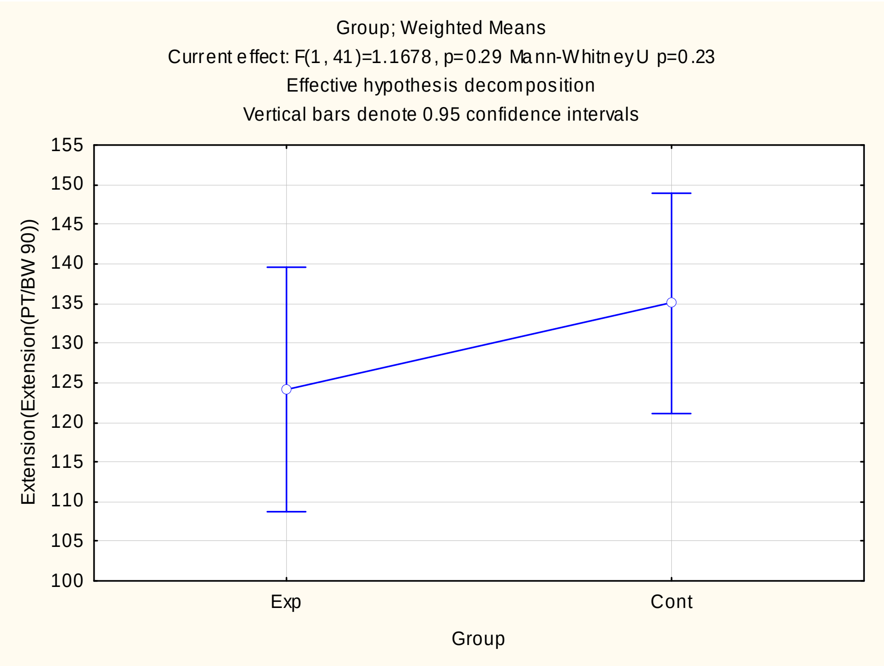


Figure 59: PT/BW isokinetic values for back extension at 90º/sec

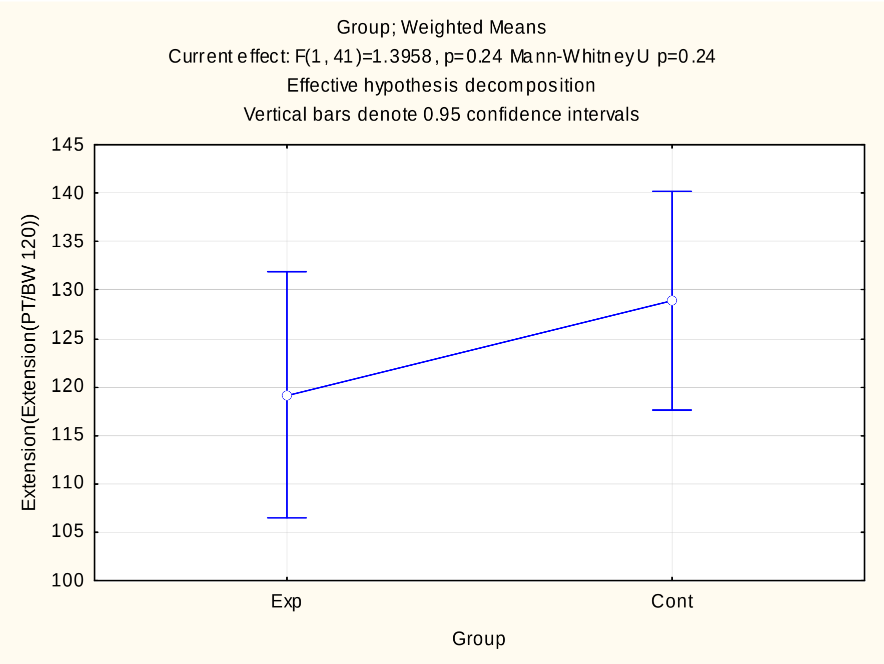


Figure 60: PT/BW isokinetic values for back extension at 120º/sec

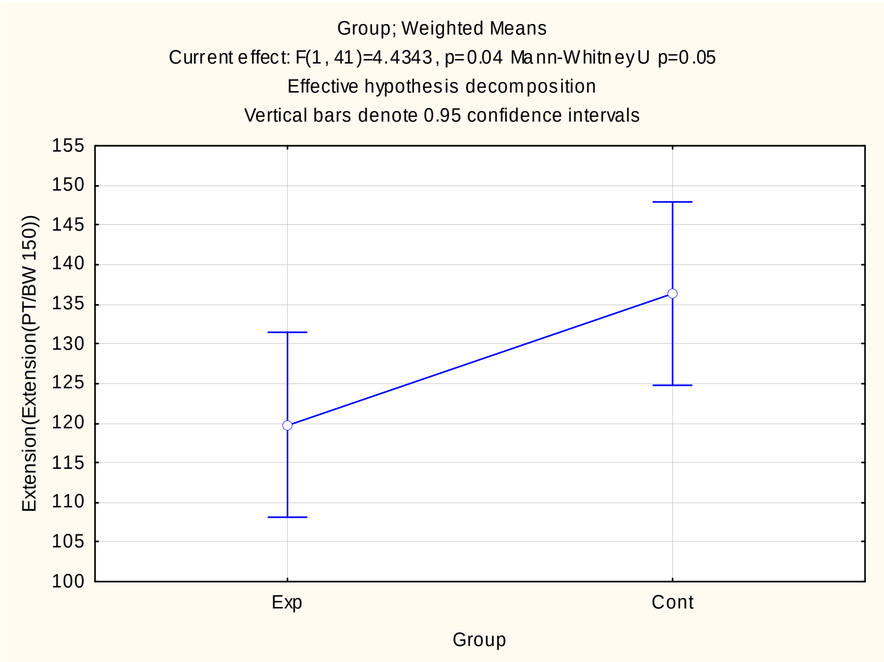


Figure 61: PT/BW isokinetic values for back extension at 150º/sec

2.5 Torque for Flexion

The following graphs show the trends for PT/BW in flexion between the experimental and control groups. No statistically significant differences were found between the two groups.

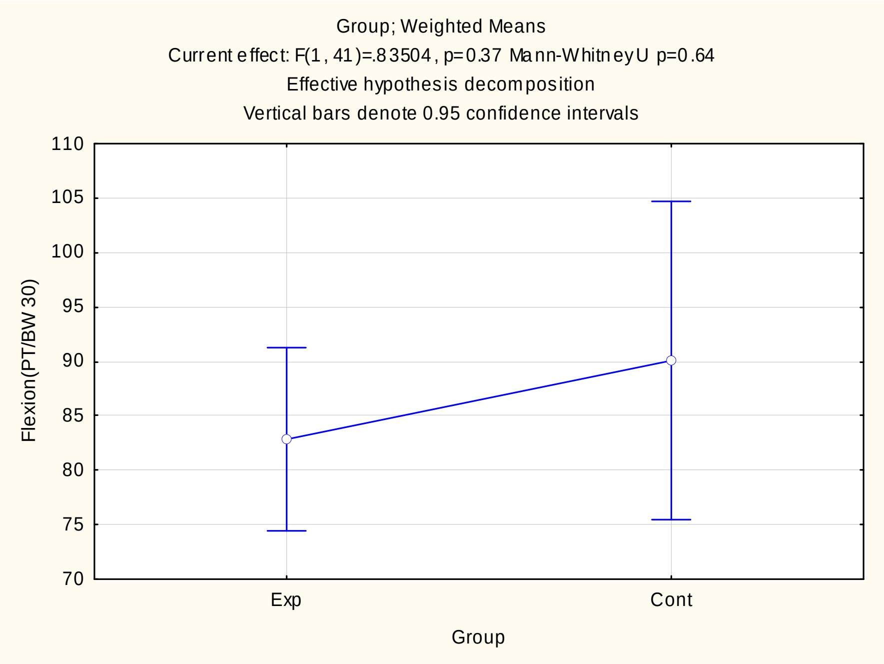


Figure 62: PT/BW isokinetic values for flexion at 30º/sec

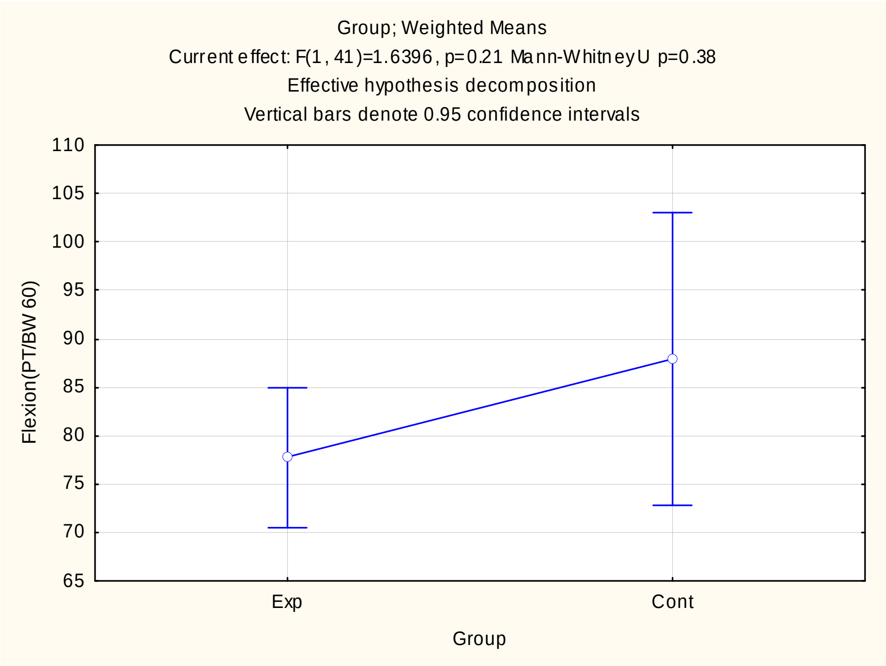


Figure 63: PT/BW isokinetic values for flexion at 60º/sec

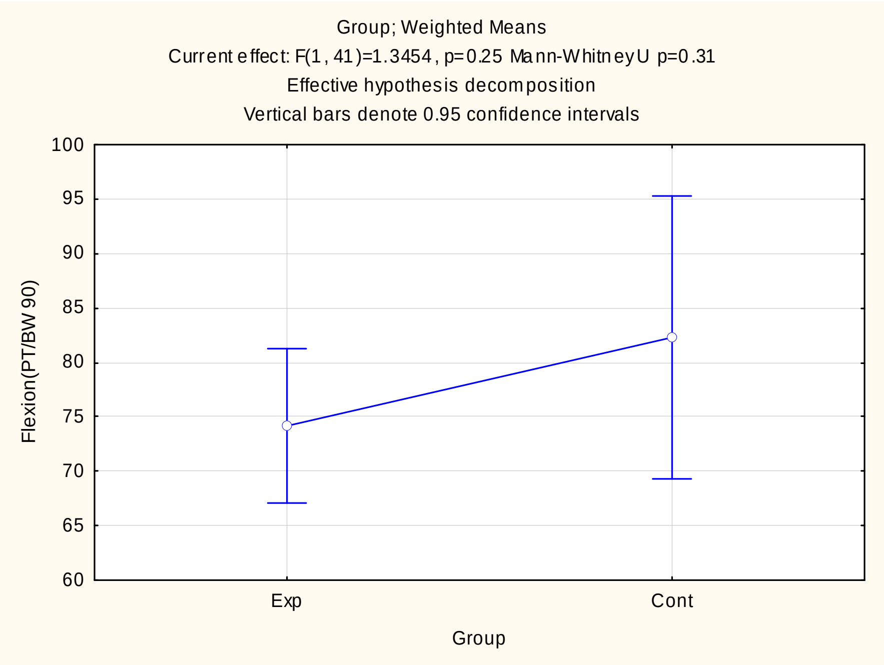


Figure 64: PT/BW isokinetic values for flexion at 90º/sec

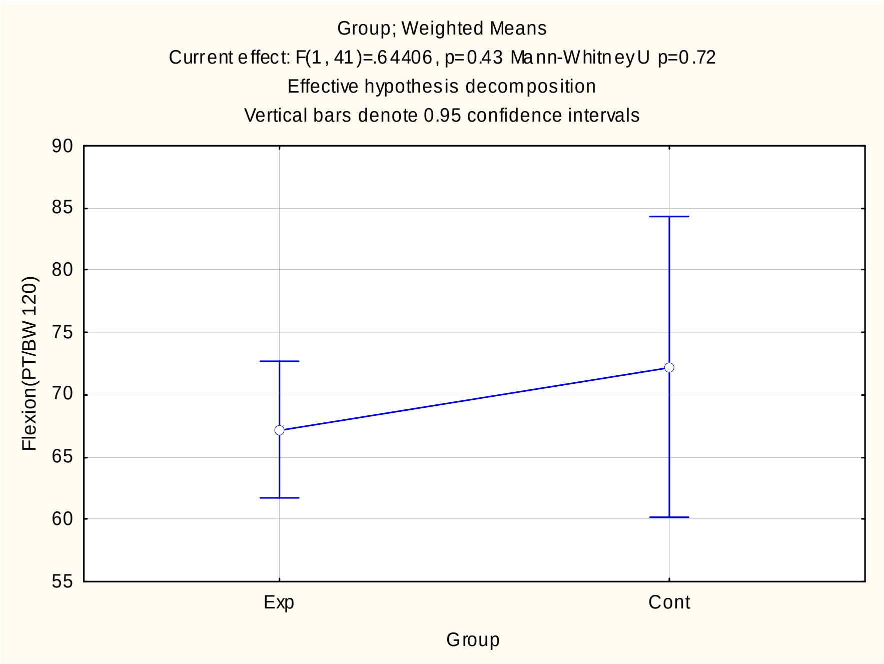


Figure 65: PT/BW isokinetic values for flexion at 120º/sec

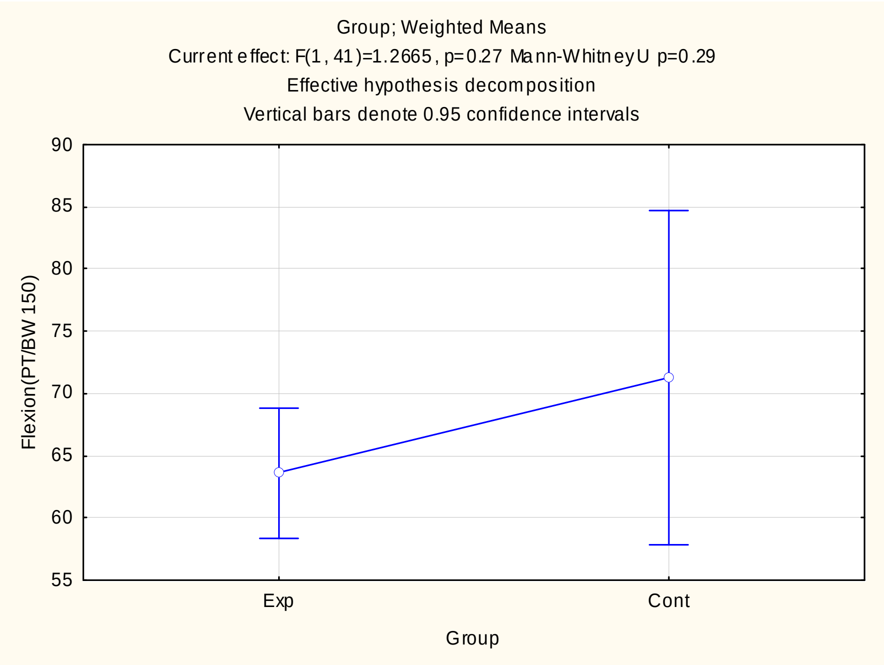


Figure 66: PT/BW isokinetic values for flexion at 150º/sec

3. Stability

Table 18 below shows a summary of the core stability test that was performed. Although the difference between the two groups was minimal, the experimental group performed marginally better on the stability test, but both groups had a poor pass rate.

Table 18: Summary of the core stability test

Core stability test		
Group	Passed	Fail
Exp	48%	52%
Control	38%	62%
Both	43%	57%

SUMMARY OF THE VALUES

Due to the lack of significant difference in the data, the two groups have been combined to produce the following mean values, which can be used for pre-screening measurements, or 'normative data', until such time as more subjects can be tested.

Table 19: Summary of isometric data

Isometric data					
105° Away		120° Away		135° Away	
Peak Torque	Avg PT/BW	Peak Torque	Avg PT/BW	Peak Torque	Avg PT/BW
191.3	101.2%	184.7	261.9%	194.4	106.7%

Table 20: Summary of concentric data

Concentric Isokinetic data		
APD Extension	APD Flexion	FER
-33.14186	23.9860465	55.8534884

Table 21: Summary of concentric data (extension)

Concentric Isokinetic Data					
Extension					
PT/BW 30°/sec	PT/BW 60°/sec	PT/BW 90°/sec	PT/BW 120°/sec	PT/BW 150°/sec	Mean PT/BW
134.423256	128.506977	129.469767	123.911628	127.846512	128.844186

Table 22: Summary of concentric data (flexion)

Concentric Isokinetic Data				
Flexion				
PT/BW 30°/sec	PT/BW 60°/sec	PT/BW 90°/sec	PT/BW 120°/sec	PT/BW 150°/sec
86.3744186	82.6790698	78.144186	69.6325581	67.3534884

Table 23: Anthropometric data

Anthropometric data						
BMI	Weight	Hams Flex	Fat %	Waist Circum	Hip Circum.	WHR
26.96	84	69.325581	25.09	90.867	103.87	0.87

Table 24: Summary of the core stability test

Core stability test		
Group	Passed	Fail
Exp	48%	52%
Control	38%	62%
Both	43%	57%

SUMMARY

A total of 43 RTG crane drivers completed testing for this study (N = 43). There were twenty two subjects in the experimental group (n = 22), which were determined by an absence of documented symptoms or back problems. There were twenty one subjects in the control group (n = 21), of which all were asymptomatic, but had a history of LBP. All subjects were males, and between the ages of 25 and 56 years old.

No statistically significant findings were found in the tests, between the experimental and control groups.

All the p-values are close to the 5% cutoff of 0.05 indicating that the differences between the groups can only be seen as trends. It also already indcates that the variables would not perform well for classifying between the 2 groups.

The following variables showed significant trends in the data, which can be used for highlighting possible differences.

Age	p=0.07
APD Extension	p=0.06
FER	p=0.06
Extension (Extension(PT/BW 150))	p=0.04

Age, APD Extension and FER showed trends of being higher in the experimental than the control group. PT/BW for back strength tended to be higher in the control group.
This suggests that, in this particular case, pre-screening can highlight deficits, but not necessarily classify an employee according to expieremental or control based on their scores. Furture testing, with more subjects, will be necessary to develop comparitive normative data.

These results will discussed in detail in Chapter Five.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

OVERVIEW

The purpose of this study was to undergo an investigation regarding morphological variables as possible risk factors for RTG crane drivers, at the POF, UK.

A protocol of tests was carried out to highlight possible risk factors that could identify those drivers who are more likely to develop low back symptoms. The tests carried out were chosen specifically to pinpoint possible characteristics that could predispose an RTG driver to a lumbar injury or condition. This data could be useful in future occupational pre-screening of RTG drivers to reduce the risk of spinal related conditions, and aid in specific, relevant rehabilitation.

1. Research Question

This study proposes an investigation regarding morphological variables as possible risk factors for RTG crane drivers, at the POF, UK.

Studies have indicated that RTG crane driving can increase the risk for LBP, due to a variety of occupational reasons. Research has yet to answer questions such as what predisposes certain drivers to injury and what determines a quick recovery and safe return to work.

The aim of this study was to investigate muscle strength and stability, anthropometric data, and a range of other factors, with regard to the role that these factors play in the development of LBP.
A protocol of tests was carried out to highlight possible morphological risk factors that could identify those drivers who are more likely to develop low back symptoms.

This data could possibly be useful to use in occupational pre-screening of RTG drivers to reduce the risk of spinal related conditions, and aid in specific rehabilitation. The long term expected outcome for gathering this information would be to decrease work related injuries, and improve sickness absence statistics associated with LBP.

2. Targeted Outcome

To reduce the occurrence of musculoskeletal injuries by identifying weakness or imbalance in the spinal flexors and extensors, stabilizers and other relevant muscle groups. To consider possible morphological factors that could subject this population group to physical risk factors within their environment.

Highlighting these risk areas will have a positive effect on the number of employees completing successful and relevant training, and therefore reduce time and money spent on unsuccessful training. Through pre-screening and early identification of these risk factors, work loss and absenteeism can be prevented or minimized, and safe return to work programs can be implemented.

3. Expected Outcome

There is strong evidence in literature to suggest that a previous history of LBP is the single, most consistent predictor of future back pain, and work loss. Specifically, history of frequency, duration of attacks, leg pain, surgery and previous sickness absence, are strong predictors of future LBP (Carter & Birrel, 2000:7). Therefore, in this study, a previous history of LBP symptoms would have been expected to be linked to poor performance in the test protocol. However, no significant differences were found between the experimental and the control group.

This is not to say that previous history is not a predictor of future back pain for this population, but rather that there could be a number of reasons why this was not a significant finding in this study. Firstly, both groups were asymptomatic at the time of testing. Due to the nature of the isokinetic testing, and for ethical reasons, all subjects needed to be asymptomatic at the time of testing. Secondly, although the control group all had a previous history of LBP, any subjects which were potentially at risk during testing, were excluded. This included subjects with previous history of lumbar surgery, severe sciatica or any other red flag conditions. There is possibly a higher causal relationship between severe lumbar pathology and future back pain.
Thirdly, the sample size for each group (experimental sample size was n=22, and the control group was n = 21) was small (n<30), and although previous history of symptoms were documented, these were not categorised specifically according to predictors (i.e. frequency of attacks, duration since last episode, and previous work absence). Therefore there could have been a wide variety of different previous history predictors within the small control group.

RESULTS

1. Strength

The results highlighted the following trends between the two groups. Firstly, APD was observed to be higher in the experimental than the control group. This suggests that the average power, or the power needed to maintain or repetitively produce a force, was higher in those previously asymptomatic patients. This affirms suspected weakness in spinal musculature with previous LBP. This is important to note in an occupation such as RTG crane drivers, due to the demand to maintain a static (forward flexed) posture, and repetitively produce force (albeit endurance) during their working shift. This is a useful value to determine in the pre-screening protocol. The group with no previous history of pain scored higher on this repetitive and endurance test, which in pre-screening is most relevant test for the RTG occupation. It can not be assumed that previous history predicts a lack in repetitive or endurance strength, but it does highlight the fact that this is an essential variable to test in an occupation such as RTG driving.

Secondly, the FER also showed a trend of being higher for the experimental group. There is an emphasis on abdominal strength in recent literature for LBP. However, this study suggests a move away from abdominal strength, and to rather focus on ratio of flexor to extensor muscle strength, within RTG drivers. The RTG driver’s forward flexion of the spine necessitates a strong concentric abdominal strength. However, almost more importantly, a strong eccentric endurance of the spinal extensors is needed to hold the spine stable against gravity, prevent an anterior shift of the lumbar vertebrae, and control lumbar lordosis, in the forward flexed position.

Thirdly, PT/BW tended to be higher in the control group. A possible contributing factor for this result is the higher body weight in the experimental group. Trends in the two groups showed that Age, BF%, Weight, and BMI were all higher for the experimental group. These values combined could result in a decreased PT/BW value when compared to body weight. The higher peak torque value is familiar in testing a younger population, such as the control group.

2. Kinanthropometric

Although no significant differences were found in the results, they do show trends in the driver population, especially with regard to kinanthropometric data. In the general population, anthropometric data such as weight, BMI, BF%, WHR and waist circumference all tend to increase with age, which explains the higher values for these measurements in the experimental group.

A high Waist circumference value is highlighted as a risk factor for the experimental group. This is due to the fact that a higher value in waist circumference could lead to decreased hip flexion. In this particular occupation, a decrease in hip flexion could result in compensation through increased flexion of the cervical and thoracic spine in order to improve visual input.

Another suspected reason for the results of the control group, was that the age (although not significant) tended to be higher in the experimental group. This would suggest that drivers are tending towards being symptomatic earlier on in their careers, than in the past. The difference in age of the group may lead to suggestion of the effects of learned response. The older drivers have more experience in RTG crane driving, and this may suggest that their muscles have adapted, and therefore perform better. Experience and learned response of the muscles, can play an important role in performing motor skills (Bischoff-Grethe *et al.*, 2004). This could also explain the higher APD scores in the experimental group, despite their higher BMI, WHR and weight values.

3. Future Pre-screening

Although the statistics were not conclusive, they have highlighted the following areas for the occupational pre-screening:

I. Endurance rather than strength

   This is in order to ensure that the testing is functional for the specific job. This will include the FER between flexor and extensor muscles.

II. Average performance deficit

   This will be tested using the original 5 speed protocol for isokinetic testing, with a 30 minute warm up.

III. Extension

   The back extensors are working against gravity in an eccentric contraction during the prolonged forward flexion.

IV. Weight, BMI, fat percentage and waist circumference values.

   These are problem areas for the testing of peak torque. If these values can be brought down, then it is suggested that the drivers will test better for peak torque. A decrease in weight, BMI and BF% would relieve some load of the spine.

V. Stability

   Due to the fact the RTG crane drivers are exposed to a higher amount of static postures, rather than dynamic lifts, the strength of ‘core stability’ muscles provides postural and spinal stability, and therefore decreases the risk for LBP.

3.1 Proposed Pre-screening Protocol

The following protocol for pre-screening purposes is proposed for all RTG crane drivers, based on trends highlighted in the study, as well as relevant literature. This protocol will address the following key factors:

i. History of back / neck problems
ii. Indication of body composition
iii. Core stability
iv. Spinal muscle strength
v. Spinal muscle endurance
vi. Flexion / extension ratio

The total time allocated for completion of the testing protocol will be 90 minutes per candidate.

CONCLUSION

The data collected in this study has provided trends within the RTG crane driver population, which have highlighted areas useful in pre-screening. The tests for the most relevant physical areas for RTG driving (i.e. APD, FER), showed the experimental group tended to be stronger and scored higher values.

Mean values for the test protocol can be used for comparison in occupational pre-screening, but is not reliable enough to pass/fail a candidate. It can be used in implementation of a rehabilitation programme for those candidates who fall well below the values for these variables. It is important to take into account a previous history of LBP in pre-employment assessments, but, in most cases, it is not a reason for denying employment

RECOMMENDATIONS FOR FURTHER STUDY

This was an investigation regarding morphological variables of RTG crane drivers, which could identify those drivers who are more likely to develop low back symptoms. Based on the findings of this study, the following recommendations for future research are made:

1. To verify the trends by repeating the study with a larger sample group (n>30), to assess if there are possible significant differences between asymptomatic and previously symptomatic drivers.

2. To test a much larger sample group (n >100) and establish norms for asymptomatic RTG drivers. This data could be used as a bench mark for pre-screening.
3. The postural nature of the RTG crane driver suggests further research should be done into the eccentric strength of the spinal extensors for this population group.
4. Further research could be done to look at the potential relationship between learned response and its affect on muscle strength and performance in these tests.
5. To investigate the response to rehabilitation programmes developed from the pre-screening protocol in relation to performance in the tests.
6. To investigate the effects of pre-screening in decreasing musculoskeletal injuries, and associated work absence.
7. If further studies are to equate LBP with work absence and investigate a causal relationship, further research needs to be done regarding yellow flags for this occupational population, and psychological factors need to be taken into account.

This is the first study done for this specific population, looking at pre-screening and normative data, and therefore it can be seen as a starting point for further investigation in this area, because of the positive trends that have been exposed.

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APPENDIX A

QUESTIONNAIRE FOR RTG & CRANE DRIVERS

IPRS

Thank you for taking the time to answer this questionnaire - your time is appreciated. The information gathered will help IPRS to assist with injury prevention strategies. Please could you answer the following questions to the best of your ability and if you have any questions, please contact us on x4842. <u>All information provided to IPRS will remain confidential.</u>

1 EMPLOYMENT AT THE PORT OF FELIXSTOWE

How long have you worked at the Port of Felixstowe? ______ years ______ months

* In total, how many have been as an RTG Driver? ______ years ______ months

* In total, how many have been as a Crane Driver? ______ years ______ months

* What other positions / roles have you done, and for how long?

Role ____________________ ______ years ______ months

Role ____________________ ______ years ______ months

Role ____________________ ______ years ______ months

What is your current position [ ]

* How long have you been in this position? ______ years ______ months

* Do you work overtime? [No] [Yes] ______ hours per week

* Have you had restrictions in this job? [No] [Yes]

If yes, please provide details

* Have you had an injury in this job? [No] [Yes]

If yes, please provide details

2 EMPLOYMENT PRIOR TO THE PORT OF FELIXSTOWE

Please could you provide some details of your previous jobs before you started working at the Port

Job / Role / Occupation	How long did you do this ?	Did you have any injuries?
	____ years ____ months	
	____ years ____ months	
	____ years ____ months	
	____ years ____ months	
	____ years ____ months	

3 SPORTING ACTIVITIES AND HOBBIES

Do you take part in regular physical activity? [No] [Yes] ______ hours per week

What physical activities do you participate in?

Activity	Intensity	Duration
	Exhausting / Average / Gentle	____ hours per month / week / day
	Exhausting / Average / Gentle	____ hours per month / week / day
	Exhausting / Average / Gentle	____ hours per month / week / day
	Exhausting / Average / Gentle	____ hours per month / week / day
	Exhausting / Average / Gentle	____ hours per month / week / day

4 INJURY HISTORY

Are you currently carrying an injury?

No	Yes

If yes, please provide details

What was the likely cause?

Have you ever had **neck pain**? | No | Yes | If yes, please continue to answer the questions below

* When

In the last 6 months	6 to 12 months ago	1 to 2 years ago
2 to 5 years ago	5 to 10 years ago	More than 10 years ago

* What do you think caused it?
* Was it diagnosed? | No | Yes | If yes, please provide details
* Was it treated? | No | Yes | If yes, please provide details
* Do you still have problems? | All the time | Occasionally | Never |

Have you ever had **back pain**? | No | Yes | If yes, please continue to answer the questions below

* When

In the last 6 months	6 to 12 months ago	1 to 2 years ago
2 to 5 years ago	5 to 10 years ago	More than 10 years ago

* What do you think caused it?
* Was it diagnosed? | No | Yes | If yes, please provide details
* Was it treated? | No | Yes | If yes, please provide details
* Do you still have problems? | All the time | Occasionally | Never |

5 ANY OTHER COMMENTS / INFORMATION

Is there anything you would like to add, or inform us about?

6 WOULD YOU LIKE TO PARTICIPATE IN FURTHER TESTING?

No	Yes

If yes, please could you provide us with the following information ....

Full Name ______________________ Tel. No ____________

Clock No ______________________ Weight ____________

Dept + Shift ______________________ Height ____________

Please post the completed questionnaire in the collection box in your mess room - thank you.

APPENDIX B
MUSCULATURE OF THE LUMBAR SPINE AND PELVIC GIRDLE

The following chart details the origins, insertions and actions of those muscles that act on the spinal coloumn, pelvic girdle and the lumbar spine. The information contained in this chart was collected from Fehrsen-Du Toit, 2005: 28; Prentice & Voight, 2001: 263; Shuenke, 2005; Kendall *et al.*, 2005:176; Kahle, 1992.

Table 25: MUSCLES OF THE LUMBAR SPINE AND PELVIC GIRDLE

MUSCLE	ORIGIN	INSERTION	BODY PART	ACTION
Erector spinae	Anterior surface of tendon attached to medial crest of sacrum, spinous processes of lumbar and T11, T12 vertebrae, posterior part of medial lip of iliac crest	Inferior angles of lower six or seven ribs	Trunk	Extension of vertebral column, draws ribs downwards
External Oblique	External surface of ribs	Linea alba and external lip of iliac crest	Trunk	Flexion and rotation, posterior pelvic tilt
Gluteus maximus	Iliac crest, sacrum and coccyx.	Iliotibial tract and gluteal tuberosity of femur.	Hip Pelvis	Extension and external rotation.
Gluteus medius	Ilium.	Greater trochanter of femur.	Hip Pelvis	Abduction and internal rotation.
Gluteus minimus	Ilium.	Greater trochanter of femur.	Hip	Abduction and internal rotation.
Iliocostalis	Ribs	Thoracic and cervical vertebra and 9th or 10th rib	Trunk	Extension and lateral flexion of vertebral column
Iliacus	Iliac fossa.	Tendon of psoas major muscle.	Pelvis	Flexion and external rotation.

Iliococcygeus	Ischial spine.	Coccyx.	Pelvis	Supports and slightly raises pelvic floor.
Iliocostalis lumborum	Iliac crest.	Lower six ribs.	Trunk	Extension.
Interspinales	Between spinous process of vertebrae		Trunk	Extension
Intertransversarii	Between transverse process of vertebrae		Trunk	Lateral flexion
Internal oblique	Anterior iliac crest, inguinal ligament and fascial layer.	Cartilage last four ribs and linea aspera.	Trunk	
Longissimus	Spinous process of last two thoracic and first two lumbar vertebrae	Spinous process of upper four to eight thoracic vertebrae	Trunk	Extension, lateral flexion of cervical spine
Multifidus	Sacrum, ilium, L1 – 5, T1 – 12 & C4 – 7.	Spinous process of higher vertebrae.	Trunk	Extension and rotation to opposite side.
Piriformis	Anterior sacrum.	Superior border of greater trochanter.	Trunk	Abduction and external rotation.
Psoas major	Transverse processes and bodies of lumbar vertebrae.	Lesser trochanter of femur.	Thigh Trunk	Flexion and external rotation. Flexion.
Pubococcygeus	Pubis.	Coccyx, urethra and anal canal.	Pelvis	Supports and slightly raises pelvic floor.
Quadratus lumborum	Iliac crest and ilio-lumbar ligament.	Lower border rib 12 and transverse process L1 – 4.	Trunk	Bends laterally on one side.
Rectus abdominis	Superior pubic crest and symphysis pubis.	Cartilage ribs 5 – 7 and xiphoid process.	Trunk	Flexion.
Rotators	Transverse process of vertebrae	Base of spinous process of the vertebrae above	Trunk	Extension and rotation to the opposite side
Semispinalis	Transverse process of thoracic vertebrae	Spinous process of first four thoracic vertebrae, and last two cervical vertebrae	Trunk	Extension, rotation

APPENDIX C

GENERAL DATA				KINANTHROPOMETRIC DATA							Core Stability	ISOMETRIC DATA					
												105 Deg Away		120 Deg Away		135 Deg Away	
Group	Clock No	Date of Birth	Age	BMI	Weight	Hams Flex	Fat %	C waist	C hip	WHR		Peak Torque	Avg Pkt/BW	Peak Torque	Avg Pkt/BW	Peak Torque	Avg Pkt/BW
			Years		kgs	degrees		cm	cm		Passed	ft-lbs	%	ft-lbs (1dp)	% (1dp)	ft-lbs (1dp)	% (1dp)
Exp	2189	13/06/53	53	30.96	97	57.5	34.2	106	110.2	**0.96**	No	208.6	97.0%	259.4	120.7%	236.7	110.1%
Exp	6409	03/03/77	29	30.82	87.0	67.5	19.67	89	100.7	**0.88**	Yes	284.0	148.7%	213.3	111.7%	268.5	140.6%
Exp	1798	16/05/06	53	29.76	83.0	57	27.6	99.2	101.4	**0.98**	Yes	101.6	55.8%	111.3	61.2%	140.1	77.0%
Exp	5497	13/11/50	56	32.93	102.0	68.5	36	112	113	**0.99**	Yes	164.5	73.4%	171.1	76.4%	182.5	81.5%
Exp	5144	28/08/67	39	24.45	69.0	90	22.9	84	93.8	**0.90**	No	202.0	132.9%	207.6	136.6%	254.5	167.4%
Exp	6555	09/01/80	26	26.53	85.0	82	23.7	90	109.3	**0.82**	No	548.3	136.4%	184.0	101.1%	216.7	119.1%
Exp	6907	24/04/61	45	30.16	101.0	81.5	32.7	108.7	108.8	**1.00**	No	191.1	86.1%	215.7	97.2%	186.9	84.2%
Exp	6594	16/02/69	37	20.45	70.0	67	19.9	78.5	97.5	**0.81**	No	108.5	70.5%	119.6	77.7%	107.1	69.6%
Exp	2771	13/03/59	47	25.00	81.0	63	28.4	101.3	101.5	**1.00**	Yes	159.1	88.4%	151.8	84.3%	142.9	79.4%
Exp	4245	25/07/63	43	23.88	69.0	82.5	28	87.8	97.7	**0.90**	No	114.2	75.1%	112.0	73.7%	106.5	70.0%
Exp	7087	16/02/80	26	30.64	96.0	61	25	96.8	115.5	**0.84**	No	187.6	88.9%	254.0	120.4%	219.9	104.2%
Exp	6443	01/08/64	42	25.06	83.0	45	29.9	100.8	105	**0.96**	No	109.0	54.0%	140.7	6970.0%	150.1	74.3%
Exp	7114	20/02/74	32	21.31	66.0	52	17.5	75	76	**0.99**	Yes	137.3	94.7%	189.3	130.6%	261.0	180.0%
Exp	4362	16/11/73	33	26.30	91.0	65	20.7	91	104.7	**0.87**	Yes	258.0	129.0%	262.2	131.1%	281.5	140.8%
Exp	2607	13/10/62	44	25.85	88.0	17.5	27.3	93	107	**0.87**	Yes	273.1	141.5%	219.0	113.5%	202.0	104.7%
Exp	2944	10/09/68	38	26.22	84.0	72	22.5	87	104.7	**0.83**	Yes	176.9	99.4%	150.1	84.3%	159.7	89.7%
Exp	1355	13/07/51	55	28.06	95.0	88	31.6	97.6	107.8	**0.91**	Yes	225.5	107.9%	222.5	106.5%	236.7	113.2%
Exp	4557	29/12/70	36	46.45	128.0	78	33	131.3	128.8	**1.02**	No	219.9	83.3%	244.7	92.7%	278.0	105.3%
Exp	2867	13/01/06	40	26.70	79.0	67	26.4	85.4	103	**0.83**	Yes	181.2	104.1%	190.2	109.3%	198.9	114.3%
Exp	7034	05/12/58	48	22.39	67.0	82	15.2	76.2	94.2	**0.81**	No	197.8	132.8%	196.0	131.6%	191.7	128.7%
Exp	4485	20/03/65	41	24.59	86.0	72.5	25.4	93	103	**0.90**	No	199.1	105.3%	162.9	86.2%	192.9	102.1%
Exp	2374	20/10/62	44	27.38	81.0	92	21.8	82	105.5	**0.78**	No	210.6	117.0%	173.4	96.4%	172.3	95.7%

APPENDIX C

GENERAL DATA			ISOKINETIC DATA													
Group	Clock No	Date of Birth	APD			Extension						Flexion				
			Extension	Flexion	FER	PT/BW 30	PT/BW 60	PT/BW 90	PT/BW 120	PT/BW 150	Mean PT/BW	PT/BW 30	PT/BW 60	PT/BW 90	PT/BW 120	PT/BW 150
			% (1dp)	% (1dp)		% (1dp)	% (1dp)	% (1dp)	% (1dp)	% (1dp)		% (1dp)	% (1dp)	% (1dp)	% (1dp)	% (1dp)
Exp	2189	13/06/53	-33.5	28	53.9	161.1	157.6	163.7	147.8	140.7	154.2	97.9	95.7	84.3	65.4	57
Exp	6409	03/03/77	-39.4	37.4	44.9	139.2	153.5	182.5	133.7	127.7	147.3	71.7	81	102	58.1	49.9
Exp	1798	16/05/06	-23.5	14.7	69.1	102.1	102.4	95.2	102.7	96.4	99.8	69.3	76.6	75.9	77.9	63.9
Exp	5497	13/11/50	12.1	53.4	53	108	115.1	112.2	88.1	61	96.9	46.1	49.9	45.3	46.4	49.8
Exp	5144	28/08/67	-33.4	34.2	49.3	139.4	134.7	124.4	125.7	132.8	131.4	59.6	61.1	60.6	59.9	52.7
Exp	6555	09/01/80	-65.8	23.7	46	162.3	150.2	146.4	158.6	143.9	152.3	90.4	85.3	70.2	62.9	54.6
Exp	6907	24/04/61	-12.7	47.5	46.6	133	113.5	112.7	104.2	116.9	116.1	71.6	63.7	60.4	55.3	53.3
Exp	6594	16/02/69	-18.9	18.3	68.7	111.5	106.8	95.8	121.6	111.1	109.4	86.4	84.8	70.5	71.7	94.2
Exp	2771	13/03/59	36.7	40.8	93.5	110.9	88.9	59.2	57.7	48.6	73.1	74.2	64.6	74.1	70.8	63.5
Exp	4245	25/07/63	-24.6	16.8	66.8	129.5	120.1	106.7	112.5	125.9	118.9	103.5	105.6	98.7	78.5	72.6
Exp	7087	16/02/80	-24.5	25.6	59.8	121.7	109.2	108.8	118.2	113	114.2	65.3	78.5	83.1	73.6	66.2
Exp	6443	01/08/64	23.5	43.2	74.2	89.2	68.2	61.2	88.4	114.5	84.3	56.2	44.1	40.8	42.3	59.9
Exp	7114	20/02/74	-10.8	33.1	60.4	118.8	115.7	126.8	82.8	105.4	109.9	79.3	78.2	71.5	63.3	74.4
Exp	4362	16/11/73	-74	10.2	51.6	164.8	171.8	171.3	144	151.8	160.7	103.1	84.3	95	76.6	74.7
Exp	2607	13/10/62	9.5	48.7	56.7	120.5	123.5	106.5	110.9	119.9	116.3	73.6	67.9	64.6	78.9	62
Exp	2944	10/09/68	-43.7	-0.6	70	125.3	128.5	124.3	124.1	123.1	125.1	91.2	92.1	83.7	78.1	76.9
Exp	1355	13/07/51	-39.4	19.9	57.5	130.4	122.4	121.8	124.2	129.9	125.7	88.9	80.3	71.8	66.7	63.3
Exp	4557	29/12/70	-19	48.4	43.4	137.7	165.5	177.4	150.4	129.2	152	122.9	76.1	65.2	48.9	43.8
Exp	2867	13/01/06	-67.3	8.9	54.5	159.2	176.7	185	186.7	167.9	175.1	103	107.5	98.8	96.9	77
Exp	7034	05/12/58	-49.6	28.7	47.7	128.1	127.9	122.9	124.4	126.5	126	92	79.5	69.7	67.8	52.2
Exp	4485	20/03/65	-32	15.1	64.3	114.9	138.8	113	123.2	130.7	124.1	106.3	94.2	77.1	69.3	67.6
Exp	2374	20/10/62	-16.4	25	64.4	122.7	99.8	114.1	92	118	109.3	69.2	58.8	68.5	68.6	70.2

APPENDIX D

GENERAL DATA				KINANTHROPOMETRIC DATA							Core Stability	ISOMETRIC DATA					
												105 Deg Away		120 Deg Away		135 Deg Away	
Group	Clock No	Date of Birth	Age	BMI	Weight	Hams Flex	Fat %	C waist	C hip	WHR		Peak Torque	Avg Pkt/BW	Peak Torque	Avg Pkt/BW	Peak Torque	Avg Pkt/BW
			Years		kgs	degrees		cm	cm		Passed	ft-lbs	%	ft-lbs (1dp)	% (1dp)	ft-lbs (1dp)	% (1dp)
Cont	6419	11/09/68	38	28.69	94	65	20.9	94	110	**0.85**	No	191.4	92.5%	201.8	97.5%	249.2	120.4%
Cont	5236	19/03/77	29	26.88	93.0	73	25	98.4	106	**0.93**	No	162.1	79.5%	200.2	98.1%	257.5	126.2%
Cont	6960	12/12/74	32	21.88	67.0	72	24	82.3	98	**0.84**	No	132.9	90.4%	153.1	104.2%	177.9	121.1%
Cont	5505	29/07/77	29	31.41	94	61	31.2	102.5	112.9	**0.91**	No	178.0	86.0%	131.4	63.5%	147.7	71.4%
Cont	6929	13/11/81	25	20.90	64.0	54.5	12.7	76.8	95.5	**0.80**	No	272.9	193.5%	192.8	136.8%	217.1	154.0%
Cont	5208	26/12/75	31	19.69	61	76.5	13	75	92.3	**0.81**	No	130.2	97.2%	119.5	89.2%	148.2	110.6%
Cont	2584	04/12/59	47	21.86	74.0	79	18.9	81.5	98.1	**0.83**	Yes	119.9	73.6%	113.9	69.9%	101.4	62.2%
Cont	2224	29/09/59	47	29.75	88	80.5	30.2	91.5	108.1	**0.85**	Yes	131.0	66.9%	153.5	78.3%	143.4	73.2%
Cont	4833	21/11/74	32	24.69	80	82.5	22	86	108.2	**0.79**	No	174.4	95.8%	178.2	97.9%	197.7	108.6%
Cont	2595	16/07/64	42	23.03	65	78.5	21.1	63	94	**0.67**	Yes	234.7	164.2%	299.1	209.2%	247.9	173.4%
Cont	4256	24/09/55	51	27.45	86.0	76.5	35.3	101	103.5	**0.98**	Yes	209.0	110.6%	203.9	107.9%	192.4	101.8%
Cont	2129	15/03/59	47	29.36	106	68.5	32.2	113	113	**1.00**	Yes	311.6	133.7%	269.4	115.6%	304.0	130.5%
Cont	5886	05/02/68	38	26.72	71	44.5	26.3	82.6	96.2	**0.86**	No	174.9	109.3%	166.2	103.9%	155.5	97.2%
Cont	4252	17/03/73	33	30.39	104	79.5	27	48.8	116.7	**0.42**	No	171.6	74.9%	163.4	71.3%	203.3	88.8%
Cont	1797	19/08/56	50	27.70	81	50.5	32.3	93.2	103	**0.90**	No	175.1	98.4%	171.8	96.5%	149.9	84.2%
Cont	7043	04/10/77	29	24.68	68.0	76	14.2	85	98	**0.87**	Yes	165.4	111.0%	176.6	118.5%	173.2	116.2%
Cont	2934	30/01/69	37	26.89	75	66.5	26.3	88	104	**0.85**	No	179.7	108.9%	197.0	119.4%	184.7	111.9%
Cont	5405	21/06/71	35	28.74	87	68	26	98.6	104.4	**0.94**	Yes	143.7	75.3%	153.4	80.3%	164.4	86.1%
Cont	6596	27/11/81	25	25.42	87.0	77.5	18.1	88.5	108	**0.82**	Yes	175.6	92.0%	221.7	116.1%	200.1	104.7%
Cont	6540	25/11/05	28	28.36	81	77.5	27.2	92	106	**0.87**	No	152.9	86.9%	174.6	99.2%	224.9	127.8%
Cont	4905	14/02/67	39	29.06	89	65	25.6	100	101.5	**0.99**	No	179.9	89.1%	149.8	74.2%	131.1	64.9%

APPENDIX D

GENERAL DATA			ISOKINETIC DATA													
Group	Clock No	Date of Birth	APD			Extension						Flexion				
			Extension	Flexion	FER	PT/BW 30	PT/BW 60	PT/BW 90	PT/BW 120	PT/BW 150	Mean PT/BW	PT/BW 30	PT/BW 60	PT/BW 90	PT/BW 120	PT/BW 150
			% (1dp)	% (1dp)		% (1dp)	% (1dp)	% (1dp)	% (1dp)	% (1dp)		% (1dp)	% (1dp)	% (1dp)	% (1dp)	% (1dp)
Cont	6419	11/09/68	35.3	-56.5	41.3	121.9	92.6	94.7	90.5	96.6	99.3	206.8	219.9	186.9	173.9	179.7
Cont	5236	19/03/77	-13.1	27.6	64	92.3	104.2	113.3	102.2	109.9	104.4	65.1	77.4	71.6	63.4	53.1
Cont	6960	12/12/74	-41	14.7	60.5	122.9	117.9	113.9	113.1	108.5	115.3	92.5	90.3	91	70.1	65.9
Cont	5505	29/07/77	-29.4	33.5	51.4	180.6	134.9	165.9	109.8	126.7	143.6	95.9	88	87.2	56.9	54.6
Cont	6929	13/11/81	-92.1	14	44.8	201.3	197.9	204.1	174.8	180.7	191.8	114.8	113.2	107.4	86.5	75.1
Cont	5208	26/12/75	-86.2	12.5	47	159.5	147.4	179	174.7	163.2	164.8	84	76.7	80.2	73.3	75.9
Cont	2584	04/12/59	-42.5	15.9	59	147.3	118.3	120.6	139.5	152.2	135.6	86.1	90.8	93.4	83.3	94.6
Cont	2224	29/09/59	-31.7	39.5	45.9	139.4	121.8	120.1	140	157.8	135.8	66.2	71.3	67.2	65.5	61
Cont	4833	21/11/74	-30.3	17.6	63.2	139.5	126.3	133.5	121.9	111.4	126.5	97.1	92.7	80	72.4	65
Cont	2595	16/07/64	-78.9	21.4	43.9	185.5	172.1	157.2	133.2	147.8	159.2	76.1	78.2	77.7	74.2	61.8
Cont	4256	24/09/55	-49.3	26.9	49	166.6	150.8	153.3	134.9	133.8	147.9	93.8	91.7	88.3	70	58.7
Cont	2129	15/03/59	-52.6	35.9	42	131.3	124.8	133.7	114.3	132.2	127.3	75.3	75.1	62.3	50.2	57.7
Cont	5886	05/02/68	-36	38.6	45.1	140	134.3	114.5	137.2	137.9	132.8	77.2	64.1	50.5	56.9	53.9
Cont	4252	17/03/73	17.1	53.4	56.2	71	89.9	74.5	75.8	86.7	79.6	45.1	46.2	40	31.7	20.8
Cont	1797	19/08/56	-27.2	21.7	61.6	119.1	95.2	103.3	112.2	115.6	109.1	76.8	69.1	61.9	61.1	59.9
Cont	7043	04/10/77	-77	-5.2	59.4	182.2	148.7	152	144.1	166.6	158.7	117.7	98	97.9	87.6	87
Cont	2934	30/01/69	-52.6	33.1	43.8	141.2	147.5	166	157.6	151.6	152.8	69.2	72.1	67.7	60.2	55.4
Cont	5405	21/06/71	-39.3	5.6	67.8	114.7	117.2	126.8	132.1	139.3	126	114.3	86.1	84.1	68.8	79
Cont	6596	27/11/81	-50.7	4.2	63.6	132.4	125.1	123.2	114.6	136.5	126.4	82.3	81.6	81.1	78.5	83
Cont	6540	25/11/05	-57.2	27.1	46.4	141.5	135.9	162.3	148.4	173.3	152.3	85.2	86.7	77.4	66.6	71.9
Cont	4905	14/02/67	-43.7	28.9	49.5	119.7	132.2	123.4	135.4	134.2	129	70.9	76.2	74.6	65.2	82.5

APPENDIX E
SUMMARY OF RAW DATA

Table 26: Summary of subjects chosen for testing

				Employed as Crane / RTG	Questionnaire Returned	Identified for testing	Number Tested
Employed as Crane / RTG	450			100%			
Questionnaires	108			24%	100%		
Identified for testing	81			18%	75%	100%	
Number Tested	43			10%	40%	53%	100%
Control	21	49%					
Experimental	22	51%					

APPENDIX F

Pre Screening Protocol

Full name: **Tel no:**

Clock #

Dept & Shift

Completed	**Time**	**Test**		
Y N	10	**Questionaire**		
Y N	5	**Body Mass Index (BMI)**	height weight BMI	
Y N	15	**Biofeedback Stability**	pass fail	
Y N	30	**Biodex ext/flex CON/CON**	30º/sec 60º/sec 90º/sec 120º/sec 150º/sec	
Y N	5	**Extension Endurance**	Test one	pass fail
			Test two	pass

fail

Y	N	25	**Anaylse Data**	
			APD	
			Flexion/extension ratio	
			Areas of concern	

Notes