CHAPTER 1:

THE PROBLEM

1.1. Introduction

A number of South African companies rely greatly on physical labour to keep the wheels turning. The longevity and sustainability of these companies are greatly dependent on a physically-able workforce. Throughout the world, including South Africa, various approaches have been identified and implemented in an attempt to ensure that employees in physically-demanding positions are properly managed from a physical work capacity point of view (Carmean, 1998; Helm *et al.*, 1999; Isernhagen, 2001; Schonstein & Kenny, 2001; Tuckwell *et al*., 2002).

This study focused on a South African electricity supply company (from here onwards referred to as SA ELEC), where biokineticists have been permanently employed to assist in taking care of the workforce through biokinetic interventions. A very large percentage of the SA ELEC workforce are “blue-collar workers” or “physical workers” and physical ability testing has, for a number of years, been used to assess potential workers (job applicants), as well as current workers, to assist in functions such as employee selection and worker screening.

Identification of insufficient physical ability and physical impairment amongst physical workers are two of the main reasons for implementing such assessment tools (van Niftrik, 1996; McKenney, 2000). Knowledge of employees in need of intervention or management can also be obtained through referral from other role players, such as line management, human resources, incapacity investigation panels and other occupational health professionals. A number of processes are in place at SA ELEC for dealing with such employees, the primary goal being to return the identified employee to full working capacity as soon as possible. The burning question has, however, always remained: “What happens to the employee in the meantime?”

This study aimed to address this question in particular and find a suitable and valuable solution to the problem. It was a natural follow-up to a previous study entitled: “Minimum Physical Requirements for the Physical Workers of an Electricity Supply Company by way of Work-Specific Physical Assessments” (Bester, 2003). The mentioned study isolated one specific physically-demanding job at SA ELEC. It focused on the identification of a test battery that was in line with the critical physical demands of this job, as well as the implementation of this test battery, to gather data in order to set minimum physical requirements for that job.

The aim now shifted to the development of a tool that could be used to assist line management in doing job accommodation when required. For the purpose of this study, the physically-demanding job in the abovementioned study was again used as an example. The physical ability test battery currently being used for this specific job was used in the development of a job accommodation tool that is task specific. Schult *et al.* (2000) mentions that functional capacity evaluation tools can be used for the purposes of job- or task modification.

1.2. Motivation

Lost work days, also referred to as “man days”, are a constant and major concern for any company (Isernhagen, 2000a; Schonstein & Kenny, 2001). This could be brought about by a number of reasons, ranging from sick leave abuse to lack of required physical ability, to temporary- or permanent physical impairment and disability (Schonstein & Kenny, 2001; Williams & Westmorland, 2002; Westmorland & Buys, 2004). Lost work days directly relate to lost productivity and usually involve other financial losses to a company, especially where workplace injuries and illnesses are concerned. Such losses mostly include disability insurance premiums, workers’ compensation premiums and worker replacement costs (Sevier *et al.*, 2000; Williams & Westmorland, 2002). Estimates suggest that annual disability costs alone could range from eight percent to fifteen percent of a company’s payroll (Williams and Westmorland, 2002).

Botha *et al*. (2000) clearly states that incapacity in the South African workplace should be managed by the organisation, and that this should be done effectively, fairly and equitably, and in compliance with the requirements of:

(a) The Constitution, 108 of 1997;
(b) The Labor Relations Act, No 66 of 1995;
(c) The Employment Equity Act, No 55 of 1998; and
(d) Contractual and Common Law Principles.

One of the preferred ways of managing the incapacitated worker is job accommodation or job modification (Bates, 1999; Burkhauser *et al.*, 1999; Lyth, 2001; Halpern, 2003; Unger & Kregel, 2003; Campolieti, 2005). Job accommodation can be defined as a pro-active, employer-based approach to: (a) prevent and limit disability; (b) provide early intervention for health and disability risk factors; and (c) foster coordinated disability management, administrative and rehabilitative strategies to promote cost-effective restoration and return to work (Williams & Westmorland, 2002). Halpern (2003) gives the following definition: In the context of return to work, accommodations are interventions that reduce the duration, frequency and / or magnitude of exposure to occupational risk factors. Williams & Westmorland (2002) state that modified work can involve modifications or adjustments of the original job to reduce physical demands or hours worked.

This study attempted to develop a method of job accommodation by focusing on the reduction of specific physical demands in a physically-demanding position. Interestingly, no literature on the job accommodation practices implemented within South Africa was available and international literature seemed to be very limited, mostly lacking the following information:

(a) examples of job accommodation tools / methods;
(b) job accommodation methods that are task specific; and
(c) job accommodation methods that focus on physically-demanding jobs.

This is not surprising, as this study attempted to do groundbreaking research in developing a tool that could fill a very large gap in job accommodation world wide. From this point of view, this study most definitely added value to the existing literature pool.

Job accommodation literature in general does, however, report on several benefits and advantages of job accommodation implementation. Information like this provided further motivation for this study, as it amplified the benefits to be gained by SA ELEC. Well-documented benefits of such an intervention include:

(a) prolonging the employment of disabled or permanently-impaired employees (Campolieti, 2005);
(b) facilitating the return to work of impaired employees (Campolieti, 2005);
(c) delaying the exit of workers to the disability rolls and prolonging their employment spells (Campolieti, 2005);
(d) assisting the company in retaining productive and qualified employees (Unger & Kregel, 2003).

Williams & Westmorland (2002) evaluated the effectiveness of modified work programmes with respect to return to work on the basis of 13 high-quality studies. The findings showed that:

(a) modified work programmes facilitate return to work;
(b) rate of return to work for injured workers who are offered modified work is double;
(c) modified return to work programmes reduce the number of lost days in half; and
(d) modified work programmes are cost effective.

Other possible benefits for SA ELEC in developing and implementing a tool that will allow task-specific job accommodation in physically-demanding jobs may include:

(a) undisrupted utilisation of employees with insufficient physical ability (with task restrictions), while they are in the process of being conditioned;
(b) assisting line management and medical practitioners in making specific task restrictions, as opposed to giving broad guidelines;

(c) prevention of new or further injury to identified employees; and
(d) improved productivity.

According to Isernhagen (2000a), most employers share similar goals when they consider their work injury prevention and disability management needs. It is interesting to note that most of these goals could be achieved by applying proper task-specific job accommodation in physically-demanding positions. These goals include, but are not limited, to the following:

(a) to decrease the cost of disability (short term and long term) for work and non-work related injuries and illnesses;
(b) to decrease the number of lost work days due to injuries and illnesses;
(c) to reduce the number of restricted days due to injuries and illnesses;
(d) to decrease recordable injuries;
(e) to reduce the number of injuries that occur to new employees;
(f) to decrease the number of new employees who resign during the first year of employment;
(g) to reduce the number of injuries associated with an ageing work force;
(h) to reduce the risk of discrimination lawsuits associated with hiring practices;
(i) to increase productivity; and
(j) to increase employee morale.

Helm *et al.* (1999) reports on an example of company savings by implementing an early return-to-work programme for 1800 employees. In this example, the company's cost per claim was $3824 in 1990. With inflation the estimated cost per claim for 1992 would have been $4970. However, the company's cost per claim was reduced to $1525 through the implementation of a work injury management programme. This company had 300 claims per year, the savings ($3445 x 300) was over 1 million for 1992. Today, 2008, the amount saved in similar circumstances can be expected to be far greater.

The reasons for this study have been stated clearly. There were, however, a number of challenges to overcome en route to developing a job accommodation tool that is practical and task specific. This section will also contain the formulation of the research problem.

Cost of job accommodation is, as could be expected, one of the main considerations as far as implementation is concerned. For many, the costs of making accommodations have proven to be extremely reasonable. It is estimated that about 52% of accommodations made by employers in the United States of America cost less than $500 to implement (Unger & Kregel, 2003).

Employers have increasingly demonstrated their capacity to provide accommodations when required. Results from several studies have provided descriptions of the type and costs of accommodations that employers have implemented in the workplace. Overall, these findings indicate that employers appear willing to grant accommodations that are perceived as straightforward, inexpensive, one-time only, not time-consuming, or easy to make, as opposed to requests for accommodations that require a sustained effort or permanent change in work arrangements (Harlan & Robert, 1998; Unger & Kregel, 2003).

Unger & Kregel (2003) also reported the following concerns or challenges that organisations face when considering the implementation of job accommodation:

(a) human resource professionals often indicate that they have limited knowledge or experience in supporting employees in need of job accommodation. Yet, they are usually viewed as a primary source of assistance in identifying and securing accommodations;

(b) business representatives express uncertainty regarding the ability of first-line supervisors to identify and develop required accommodations;

(c) managers and supervisors within organisations possess limited knowledge of disabilities, accommodations and other related requirements. Subsequently, requests for accommodations may even go unaddressed, or be denied; and

(d) research that describes employers' knowledge and utilisations of accommodations, and the extent to which organisations are able to adequately address the support needs of workers, is lacking.

According to Johnson and Miller (2001), the preferred outcome for all parties involved in the return-to-work process is return to work, same employer, and same job. Functional capacity evaluations must therefore be able to effectively match the physical abilities of the worker to the physical requirements of the job. They also state that evaluations that address job specificity can facilitate effective return to work with modified duty.

All of the mentioned challenges and concerns could also be generalised to SA ELEC and, in fact, similar concerns are often raised when job accommodation is required within the mentioned company.

Halpern (2003) makes mention of a few critical considerations and questions that need to be addressed before any job accommodation process is started:

(a) who the role-players are;
(b) what job demands need to be analysed;
(c) what information is useful for all involved in the process; and
(d) what potential problems exist in implementing the intervention.

It is also stated by Halpern (2003) that the answers to these questions will affect the cost of the job accommodation process.

A number of reasons for applying job accommodation have been given so far. Furthermore, mention has been made of benefits that usually accompany job accommodation, as well as challenges that face the researcher in developing a job accommodation tool that will allow the company concerned to enjoy the mentioned benefits.

The research problem can now be summarised as the need for SA ELEC to implement a work-specific job accommodation method in jobs where a degree of physical ability is an inherent requirement of the job. Furthermore it can be said that a job accommodation tool that meets these requirements needs to be developed in order for the mentioned company to enjoy the benefits recorded in other companies throughout the world. The bottom line is that no company can afford to ignore interventions that will add value and reduce risk. It can safely be stated that proper job accommodation will definitely provide the opportunity to do just that.

1.3. Research Question

For this study, the following research question was used:

Can physical ability tests be used to develop a task-specific job accommodation tool for a physically-demanding position?

1.4. Research Hypothesis

In the light of the aim of this study, the following research hypothesis was formulated:

Physical ability tests can be used to develop a task-specific job accommodation tool for a physically-demanding position.

A sub-hypothesis was also formulated from the main hypothesis:

The mentioned job accommodation tool will contribute in developing the field of corporate biokinetics, specifically related to jobs where physical ability is an inherent requirement of the job.

1.5. Goal of the study

The following goal was set before the study commenced:

Develop a task-specific job accommodation tool for a physically-demanding position.

1.6. Objectives of the study

This study aimed to achieve the goal through the following objectives:

- building a theoretical frame of reference on existing literature, with specific focus on topics such as physical ability testing, norm calculation, job analysis and job accommodation;
- identification of the physically-demanding position to be used as example during the course of this study;
- description of the outputs and critical physical demands associated with the identified position (job analysis, etc.);
- identification and description of a test battery that will be suitable in assessing the critical physical demands of the mentioned position;
- description of the calculation of the minimum physical requirements for the mentioned position;
- step-by-step description of the process in developing the actual task-specific job accommodation tool; and
- instructions on the implementation of the job accommodation tool.

1.7. Research approach

This study followed a quantitative research approach and the two quantitative techniques that were used are generally referred to as “content analysis” and “existing statistics.”

Content analysis is a technique for examining information, or content, in written or symbolic material. The researcher identifies a body of material to analyse. The material can be anything written, visual, or spoken that serves as a medium for communication. Content analysis is a technique for gathering and analysing the content of text (Neuman, 1997). During this study, the job-analysis phase made use of content analysis.

As part of the development of the task-specific job accommodation tool, the critical physical job outputs / tasks associated with the identified position needed to be identified and analysed. Thorough and precise content analysis was conducted for this purpose. The official "SA ELEC job description document" of the applicable job was used for content analysis.

In existing statistics research, a researcher locates a source of previously-collected information. The information is then reorganised, combined, or reassembled in new ways to address the research question (Neuman, 1997). Burns (2000) refers to this technique as descriptive statistics. For the purposes of this study, existing statistics were used when developing the actual job accommodation tool by combining the information from the job analysis and the existing physical ability norms for the applicable job.

1.8. Research design

A research design is essentially a plan or strategy aimed at enabling answers to be obtained to research questions (Burns, 2000).

In essence, this study followed a research method known as action research. Burns (2000) states that the focus in action research is on a specific problem in a defined context. One of the main goals that set action research apart from other forms of research is the requirement of "finding a solution" (Dane, 1990). The purpose of action research is to develop new skills or new approaches and to solve problems with direct application to applied settings (Edginton *et al.*, 1992).

Reference was also made to cross-sectional descriptive research. The existing minimum physical requirements that were to be used during this study followed this approach, and since the development of the task-specific job accommodation tool is described from start to finish, a large part can be described as cross-sectional and descriptive.

Cross-sectional research addresses our need to document facts at a single moment in time. It is the research equivalent of the "polaroid moment." A cross-sectional design obtains information from a single group of respondents at a single point in time without any attempt to follow up (de Vaus, 2001; Ruane, 2005). Obtaining information from a cross-section of a population at a single point in time is a reasonable strategy for pursuing many descriptive research projects (Ruane, 2005).

Descriptive research can offer a detailed picture of a group. In painting a descriptive picture, this kind of research strives to be as accurate as possible. Measurement and sampling are important issues in descriptive research (Ruane, 2005). Descriptive statistics are often used in descriptive research to summarise a set of data (McBurney, 1994).

1.9. Research procedure and strategy

- identify a physically-demanding position to be used for the purposes of this study;
- do a thorough job analysis to identify all physically-demanding job outputs;
- do an analysis of each job output to identify all tasks where physical ability is an inherent requirement;
- do an analysis of each task to ensure proper understanding of all the critical physical demands that are involved in each physically-demanding task;
- list all the critical physical demands applicable to the job;
- identify an objective test for each of the critical physical demands;
- determine the minimum physical requirements for each test;
- determine which tests are applicable to which tasks through the critical physical demands;
- determine the weighting of each physically-demanding job output by looking at frequency, duration and importance of each output in everyday work (this information will be used to determine the percentage of the total outputs a person will be able to perform);
- finalise the task-specific job accommodation tool with applicable documentation; and
- do three case studies to explain the use and value of the job accommodation tool.

1.10. Definitions of key concepts

Job accommodation

In the context of return-to-work, job accommodations are pro-active, employer-based interventions that reduce the duration, frequency and / or magnitude of exposure to occupational risk factors.

Physical ability testing

Examination of the critical physical parameters of workers according to the inherent physical requirements of their jobs.

Physically-demanding job outputs

Job outputs where a minimum physical ability is an inherent requirement.

Physically-demanding tasks

Physically demanding job outputs are broken down into physically-demanding tasks.

Critical physical demands

Physically-demanding tasks are further broken down into critical physical demands. These measurable physical attributes can be described as movements and exertions in their simplest form.

Minimum physical requirements

The minimum physical test scores required to show whether an individual possesses the physical ability to perform a specific physically-demanding job.

Job analysis

The process followed by a researcher in order to obtain a clear and precise understanding of the critical physical demands for each of the physical tasks that are crucial to the successful performance of a physically-demanding job.

Impairment

Disease, disorder or injury. Changes in normal body function or structure as a result of significant deviation or loss.

Disability

Reduction or loss of an ability to perform an activity due to disease, disorder or injury. It impacts on personal, social or occupational demands.

Incapacity

Alteration of an individual’s capacity to perform the essential outputs of the job in which he / she is employed, due to impairment.

CHAPTER 2:

LITERATURE REVIEW

2.1. Physical ability testing (PAT) for physically-demanding work

2.1.1. What is PAT?

Occupational health aims to promote and maintain the highest degree of physical, mental and social well-being of workers in all occupations; to prevent decline in health caused by their working conditions; to protect workers in their employment from risks resulting from factors adverse to health; and to place and maintain workers in an occupational environment adapted to their physiological and psychological capabilities. In summary, it aims to adapt work to the workers and each worker to his or her job (Serra *et al.*, 2007). Arwedson *et al.* (2007) furthermore states that active keep-fit measures, which would include physical ability testing, are one of the main categories of health-related factors.

Physical ability testing (PAT) is a tool used to assess an individuals' physical abilities to perform specific work-related physically-demanding tasks. It is the preferred ergonomic approach for those physically-demanding jobs that cannot be redesigned. The goal is to match the workers' physiological capabilities with the physical demands of the job (Bester, 2003; Arvey, 2005). McKenney (2000) describes this as a comprehensive, objective test of an individuals' ability to perform work-related tasks. Serra *et al.* (2007) states that the assessment of fitness for work is defined by most as the evaluation of a workers' capacity to work without risk to their own or others' health and safety. They then go further and state that the assessment of fitness for work is defined as the determination of whether an individual is fit to perform his or her tasks without risk to self or others. Importantly, McKenney (2000) also states that only trained health professionals with extensive training in anatomy, physiology, kinesiology and the effects of disease / injury and exercise on the human body should administer such tests.

Employment testing for physically-demanding work typically includes tests that are based on either task sampling (work samples or job simulations), or tests measuring physical ability constructs, such as muscular endurance. Tests involving work samples are often defended on the basis of content validity. Tests measuring physical ability constructs are often defended on the basis of criterion-related validity (Jackson, 1994; Hough *et al.*, 2001).

Strength testing is the most effective PAT technique for materials-handling tasks. The hypothesis behind this approach is that there is a relationship between the probability of injury and percentage of strength capacity used by the worker in job performance (Jackson, 1994). Other testing techniques often used for the purposes of measuring task- or work-related physical ability include muscle endurance, muscle power, flexibility, cardiovascular fitness and balance (Hogan & Quigley, 1994; Hough *et al.*, 2001; Schibye *et al.*, 2001).

In most cases where PAT is used, the test battery is usually accompanied by minimum physical requirements, also known as “cut scores” or “cut-offs” (Jackson, 1994; Meier, 1998; Biddle & Sill, 1999; Bester, 2003). This is the score that a job applicant must obtain to be considered for a job, or to adhere to the inherent physical requirements for a specific job (Jackson, 1994).

2.1.2. Why implement PAT?

Large companies usually have a number of departments that focus on innovative methods to improve the ability of workers to do work. Examples of such departments include Human Resources, Production, Education, Safety and Occupational Health. These departments are also concerned with decreasing human and financial costs of work-related illness and injury. Similarly, workers (and unions) maintain their place in the competitive work environment by seeking work that will financially reward them, be satisfying, be safe, and provide a fully productive worklife (Winkel & Westgaard, 1996; Isernhagen *et al.*, 1997; Isernhagen, 2000a). According to Hofmann and Kielblock (2007), overall physical work fitness contributes to improved productivity and the maintenance of good health and safety. Another effective method to ensure that these requirements of employers and workers are met is to “match the worker and the work.” If a worker has the ability to safely do the work, future injury created by a mismatch of ability and work requirements can be reduced. Effective preventative approaches address the worker, the work and the worksite. The categories that allow matching the worker to the work are: (1) ergonomics; (2) education; (3) pre-work screening; (4) fitness; and (5) safe work practices (Isernhagen, 2000b).

The ever rising incidence of disability among the worldwide working population is a matter of great concern (Chavalinitikul *et al.*, 1995; Van Niftrik, 1996). Extremely large amounts of money are lost every year due to workers' compensation claims (Lukes & Bratcher, 1990; Malan & Kroon, 1992; Greenberg & Bello, 1996). Lower back pain has traditionally been the most costly industrial injury (Greenberg & Bello, 1996). Acute and chronic work-related injuries may be attributed to excessive force demanded by the task (especially by tasks such as lifting, carrying, pushing and pulling), inadequate osteoarticular structures, or insufficient general- or local aerobic capacity (Capodaglio *et al.,* 1997; Bester, 2003).

Strong epidemiological evidence shows that the physical demands of work (lifting, bending, twisting, etc.) can be associated with increased reports of back symptoms and injuries (Frymoyer *et al.*, 1983; Capodaglio *et al.*, 1997; Hadler, 1997; Waddell & Burton, 2001). Strong evidence also suggests that the physical demand of work is a risk factor for the incidence of lower back pain (Burton, 1997; Waddell, 1998; Waddell & Burton, 2001).

Garg and Moore (1992) identified two approaches as the most effective strategies in preventing lower back pain in industry. According to them, the scientific literature shows that "job-specific strength testing" and "ergonomic job design" are both effective in the prevention of lower back injuries. Kelsh and Sahl (1996) support these views by mentioning that physical capacity differences and workplace designs are two of the main reasons why females in physically-demanding positions are at a higher risk of occupational injuries.

Seeing that women now account for a larger percentage of the active workforce and that there are now more women in occupations that historically have had high injury rates, this is a significant observation (Davis & Dotson, 1987; Kelsh & Sahl, 1996). Davis and Dotson (1987) rightly states that the ever-increasing number of women applying for physically-demanding work puts pressure on employers to make use of some sort of pro-active approach to try and prevent injuries in the work place.

Isernhagen (2000b) points out the following issues that are addressed by the measurement of work requirements and worker capabilities:

(1) employers expect to get a full day's work for a full day's pay and workers expect to be rewarded for their efforts in that full day of work;

(2) from a medical viewpoint, answers about who is safe to work in particular jobs, or when it is safe and appropriate to return an injured worker to work, require objective information on matching the worker and the work;

(3) from a legal standpoint, anti-discrimination laws prevent employers from discriminating against workers regarding disability, gender, age or nationality, and non-discrimination will be facilitated by focussing on the capability of workers, rather than the demographics;

(4) case management decisions on work disability require a medically / legally objective method of identifying which physical aspects of the job can be done by a worker who has definable medical / functional status; and

(5) governmental guidelines in the safety and health areas improve safety and prevent injury or catastrophic problems in the workplace, hence the work should be designed to be safe and match the worker.

All in all there are a number of well-documented benefits associated with PAT. The main benefits of matching the work and the worker include injury prevention, decreased re-injury rates, decreased (employee) turnover and improved production (Mamansari & Salokhe, 1996; McKenney, 2000).

It is, however, very important to take note of some of the main factors / criteria to take into account before assessing fitness for work. These criteria will go a long way in determining the effectiveness of the intervention, according to Serra *et al.* (2007). They state that the assessment should:

(1) determine a worker's physical capacity in relation to his or her work;
(2) determine a worker's health and safety risk in relation to his or her workplace;
(3) adhere to ethical considerations;
(4) adhere to economical criteria; and
(5) adhere to legal requirements (Serra *et al.*, 2007).

2.1.3. Important considerations in developing PAT

In order to ensure proper and effective implementation of PAT in any physically-demanding job, there are a number of very important considerations that one has to adhere to. Some of these will be discussed in more detail at a later point in this chapter, but a short description will be given here. Firstly, it is critical that a thorough job analysis is done (Keyserling *et al.*, 1990; Isernhagen, 2000a; Toeppen-Sprigg, 2000; Janowitz *et al.*, 2006). Furthermore, it is very important to develop a test battery that is safe, valid, reliable, objective, credible and standardised (Shrey & Lacerte, 1997). Following is a short discussion of each of these important considerations.

2.1.3.1. Job analysis

According to Fleishman (1979), the most important part of successful job-related physical testing lies in determining, through proper job analysis techniques, what the tasks of the job are and what abilities are relevant for performing the required tasks. Exposure to physical load can be very complex, involving multiple spheres of activity such as lifting, pushing, grasping, and the concomitant characteristics of these activities such as velocity, acceleration, frequency and duration. Job evaluation techniques, although varied, all attempt to capture this complexity within a manageable construct (Janowitz *et al.*, 2006). Shrey and Lacerte (1997) states that the test administrator must have a clear and precise understanding of the physical demand for each of the tasks that are crucial to the successful performance of the job. A functional job analysis that is useful must have validity and accuracy (Toeppen-Sprigg, 2000).

2.1.3.2. Safety

The safety of the individual must be of primary concern to the assessment administrator (Mamansari & Salokhe, 1996; Shrey & Lacerte, 1997). Equipment and procedures must not place undue risk of injury or re-injury on the individual. The assessment administrator must take into account the specific condition of the individual; a procedure that is safe for one person may not be safe for another. Also, previously injured or disgruntled workers, who may be looking for ways to "get back at the system," require caution. Such individuals may look for opportunities to claim that the testing procedure caused an injury and that they are therefore entitled to additional compensation (Shrey & Lacerte, 1997; Bester, 2003).

2.1.3.3. Validity

Validity is usually considered to be the extent to which an instrument measures what it is intended to measure (Innes & Straker, 1999). Internal and external test validity issues must be identified and resolved when designing a test battery. Internal validity deals with whether the assessment actually measures what it is supposed to measure (McBurney, 1994; Neuman, 1997; Shrey & Lacerte, 1997). To achieve strong internal validity, the testing procedure must have sufficient controls so that influencing factors are eliminated. For example, a static (isometric) lifting test can have a high level of internal validity, because many of the variables involved in the lift can be controlled: the speed of the movement (i.e., no speed), the lifting posture and the lift duration. A dynamic lifting test may have a much lower degree of internal validity, since the above-mentioned variables cannot be controlled (Shrey & Lacerte, 1997; Bester, 2003).

External validity concerns the generalisation of the test results to a larger population or application. To achieve strong external validity, the test needs to have a close resemblance or approximation to the actual work task. The closer the assessment simulates the actual work task, the higher the external validity (McBurney, 1994;

Neuman, 1997; Shrey & Lacerte, 1997). It is difficult to design a test that has both strong internal and external validity. As control of the task increases, external validity decreases. The assessment administrator needs to decide which factor is more important and design the test accordingly (Shrey & Lacerte, 1997; Bester, 2003).

Jackson (1994) also mentions two other types of validity when talking about work-related physical assessments. They are "content validity" and "criterion-related validity." Content validity refers to the idea that a test should sample the range of exertions represented by the task being tested (McBurney, 1994; Neuman, 1997; Thomas & Nelson, 2001). Criterion validity uses some standard or criterion that is known to indicate a single construct within a task accurately (McBurney, 1994; Neuman, 1997; Thomas & Nelson, 2001).

2.1.3.4. Reliability

A test cannot be considered valid if it is not reliable (Thomas & Nelson, 2001). Statistical reliability is a measure of consistency. It gives you the same result each time the same thing is measured. Assessment reliability deals with the ability of the equipment and testing procedure to consistently reproduce a given measurement. There should not be any statistical difference in the outcome of multiple trials if an individual provided consistent effort on a given piece of equipment (Neuman, 1997; Shrey & Lacerte, 1997; Tuckwell *et al.*, 2002). Equipment reliability is usually demonstrated through studies, using motivated subjects who are assumed to give consistent, maximum efforts. Performance reliability deals with the consistency in the performance of a given task (Shrey & Lacerte, 1997).

2.1.3.5. Objectivity

Legal defensibility is enhanced by conclusions based on objective, rather than subjective, data. Objective findings are unbiased, impartial and not influenced by the assessment administrator (McBurney, 1994; Neuman, 1997; Shrey & Lacerte, 1997; Bester, 2003). This kind of data includes various measurements, such as force of an exertion, variation between repeated trials and change in heart rate. The information is measurable and reproducible (McBurney, 1994; Neuman, 1997; Shrey & Lacerte, 1997; Bester, 2003).

The collection of subjective data can also be of significant value, but subjective data, such as rating scales and open-ended questions, are open to bias and interpretation of both the assessment evaluator and the worker (McBurney, 1994; Neuman, 1997; Shrey & Lacerte, 1997; Bester, 2003). Great care must be taken in providing guidelines for the collection and interpretation of this type of data (Shrey & Lacerte, 1997).

2.1.3.6. Performance credibility

Performance reliability is often used to determine performance credibility, based on the assumption that an individual will produce similar outcomes in a series of maximal trials. Studies have found force coefficients of variation to range from 8.6% to 15.4% when measuring isometric lift performances. However, performance inconsistency can have several possible causes other than a sub-maximal performance, namely:

(1) a learning effect can take place from one trial to the next, resulting in improved performance during the later trial;
(2) pain on some of the trials could result in inconsistent effort;
(3) poorly designed assessment procedures, or equipment that lacks standardisation, could result in inconsistent measurements; and
(4) inconsistent effort can result due to the individual not understanding the procedure (Shrey & Lacerte, 1997; Bester, 2003).

2.1.3.7. Standardisation

Assessment standardisation deals with the uniformity of the assessment procedure from one assessment to another and makes it possible to compare different test results on a common base (Neuman, 1997; Shrey & Lacerte, 1997; Bester, 2003). The oral instructions, task demonstrations, subject placement, data collection and data analysis should be documented and followed each time the assessment is administered. These factors should never change, regardless of the individual administering the assessment (Shrey & Lacerte, 1997; Bester, 2003).

2.2. Important physiological components involved in physical ability testing

During physical activity, which includes physical labour and physical ability testing, changes occur at a physiological level. A few of these changes are mentioned by Vander *et al.* (2001):

(1) increased skeletal-muscle blood flow;
(2) increased systolic arterial pressure;
(3) decreased total peripheral resistance;
(4) increased cardiac output;
(5) increased activity of the skeletal-muscle pump;
(6) increased depth and frequency of inspiration;
(7) chemical changes in the involved muscles;
(8) activation of chemoreceptors and mechanoreceptors in the active muscles; and
(9) changes in the skeletal-muscle fibers.

This section will take a deeper look at the physiological components involved in physical ability testing. The following components are of critical importance during physical ability testing and of great relevance in terms of this thesis: muscular strength; muscular endurance; flexibility; cardiovascular fitness; and balance. Due to the natural onset of muscle fatigue following physical activity, this will also be discussed.

2.2.1. Muscular strength

Muscular strength may be defined as the maximum force / tension a muscle or, more correctly, a muscle group can generate / exert against a resistance in one maximal effort / contraction (McArdle *et al.*, 1991; Arnheim & Prentice, 1993; Fox *et al.*, 1993; Corbin & Lindsey, 1994; Foss & Keteyian, 1998; Powers & Howley, 2001; Heyward, 2006; Powers & Howley, 2007). Hough *et al.* (2001) defines muscular strength as the ability to apply or resist force through muscular contraction.

At this point it also becomes appropriate to discuss the molecular mechanism of contraction. According to Vander *et al.* (2001), the term contraction, as used in muscle physiology, does not necessarily mean "shortening". In actual fact it only refers to the turning-on of the force-generating sites, the cross bridges, in a muscle fibre. When force generation produces shortening of a skeletal-muscle fibre, the overlapping thick and thin filaments in each sarcomere move past each other, propelled by movements of the cross bridges. During this shortening of the sarcomeres, there is no change in the lengths of the filaments. This is known as the sliding-filament mechanism of muscle contraction. Whole muscles are made up of many muscle fibres organised into motor units (Powers & Howley, 2007).

Here follows an in-depth look into the physiology and biomechanics underlying the different types of muscular contraction.

2.2.1.1. Isotonic contraction

Isotonic contraction is one of the most familiar types of contraction. It is sometimes also referred to as a dynamic contraction. This type of contraction causes the muscle to change length, either shortening (concentrically) or lengthening (eccentrically) (McArdle *et al.*, 1991; Fox *et al.*, 1993; Corbin & Lindsey, 1994; Foss & Keteyian, 1998; Kroemer *et al.*, 1999; Vander *et al.*, 2001; Saladin, 2007). In actual fact, the term "dynamic contraction" is more accurate, because isotonic literally means "same or constant" (iso) "tension" (tonic). In other words, an isotonic contraction supposedly is one that produces the same amount of tension while shortening as it overcomes a constant resistance. However, this is not true for intact muscles, because the tension exerted by a muscle as it shortens is affected by several important factors, three of which are discussed below (Fox *et al.*, 1993; Foss & Keteyian, 1998; Heyward, 2006).

2.2.1.1.1. Muscle length–tension relationship

An isolated muscle can exert its maximal force, or tension, while in a stretched position. The range of peak tension is slightly greater than the resting length of the muscle as it would be positioned in the body. As the muscle shortens, less tension can be exerted. For instance, at about 60% of its resting length, the amount of tension that a muscle can exert approaches zero. The physiological reason for this is explained as follows: with excessive shortening, there is an overlap of actin filaments, such that the filament from one side interferes with the coupling potential of the cross bridges on the other side. Because there are fewer cross bridges "pulling" on the actin filaments, less tension can be developed. If the length of the muscle (sarcomere) is optimal, all cross bridges can connect with the actin filaments and maximal tension can be developed. If the sarcomere is, however, stretched to such an extent that the actin filaments are pulled completely out of the range of the cross bridges, the bridges cannot connect and no tension can be developed (Guyton, 1991; Fox *et al.*, 1993; Foss & Keteyian, 1998; Vander *et al.*, 2001; Fox, 2006; Saladin, 2007).

2.2.1.1.2. Angle of pull of muscle

From the previous discussion one might conclude that a person can lift the heaviest load when the muscle is at resting stretched length. However, this is not true, because the intact mechanical system with which we lift objects involves the use of both muscles for force and the use of bones for levers. It is the arrangement of muscles, bones and other important components together, such as joints and body contours, that determines the final effect (Fox *et al.*, 1993; Kroemer *et al.*, 1999; Foss & Keteyian, 1998). If we let the joint angle represent the angle of pull of the muscle on the bone to which it is attached, we can see that, for the elbow (forearm) flexor muscles, for instance, the strongest force is exerted between joint angles of 100 and 140 degrees (180 degrees is complete extension). At a joint angle of 180 degrees (the position of resting stretch), the muscle group exerts a much weaker force (Fox *et al.*, 1993; Foss & Keteyian, 1998).

2.2.1.1.3. The speed of shortening

Not all skeletal-muscle fibres have the same twitch contraction time. Some fast fibres have contraction times as short as 10 ms, whereas slower fibres may take 100 ms or longer. The duration of the contraction time depends on the time that cytosolic calcium remains elevated so that cross bridges can continue to go through the cross bridge cycle which occurs repeatedly during muscle contraction (Vander *et al.*, 2001). Each cycle consists of four steps:

(1) attachment of the cross bridge to a thin filament (containing the contractile protein called actin);
(2) movement of the cross bridge, producing tension in the thin filament;
(3) detachment of the cross bridge from the thin filament; and
(4) energising the cross bridge so that it can again attach to a thin filament and repeat the cycle (Vander *et al.*, 2001).

There are three basic types of muscle fibres:
(1) slow-twitch oxidative fibres;
(2) fast-twitch oxidative fibres; and
(3) fast-twitch glycolytic fibres (Guyton, 1991; Arnheim & Prentice, 1993; McArdle *et al.*, 1996; Vander *et al.*, 2001; Plowman & Smith, 2003; Malina *et al.*, 2004; Martini, 2006; Powers & Howley, 2007).

Fast-twitch fibres are basically anaerobic. In contrast, slow-twitch fibres are aerobic. Fast-twitch fibres are responsible for speed or speed-power activities, such as sprinting or lifting heavy objects. Slow-twitch fibres come into play in endurance activities. The fast-twitch oxidative fibres lie somewhere in the middle, but closer to the fast-twitch glycolytic fibres than to the slow-twitch oxidative fibres (Guyton, 1991; Arnheim & Prentice, 1993; McArdle *et al.*, 1996; Martini, 2006). There are also size differences. Glycolytic fibres generally have much larger diameters than oxidative fibres (Vander *et al.*, 2001; Martini, 2006).

At any given velocity (speed) of movement, the torque (the product of force multiplied by the lever arm distance) produced is greater the higher the percentage of distribution of fast-twitch (FT) fibres in the muscle. By the same token, at any given torque produced, the velocity of movement is greater the higher the percentage of distribution of FT fibres. These relationships point out that FT fibres are capable of producing greater peak muscular tension and a faster rate of tension development than are ST (slow-twitch) fibres (Fox *et al.*, 1993; Foss & Keteyian, 1998; Vander *et al.*, 2001). The biochemical and physiological properties related to these contractile dynamics are the fibres' myosin

ATPase activities and their rates of calcium release and uptake from the sarcoplasmic reticulum. Both of these properties are higher within the FT fibres than in the ST fibres (Guyton, 1991; Fox *et al.*, 1993; Foss & Keteyian, 1998; Vander *et al.*, 2001; Powers & Howley, 2007).

2.2.1.2. Isometric contraction

The term “isometric” literally means “same or constant” (iso) “length” (metric). In other words, isometric contraction (or action) occurs when tension is developed, but there is no change in the external length of the muscle (Plowman & Smith, 1997; Foss & Keteyian, 1998; Vander *et al.*, 2001; Plowman & Smith, 2003; Martini, 2006; Saladin, 2007). The muscle does not shorten, because the external resistance against which the muscle is pulling is greater than the maximal tension (internal force) the muscle can generate. Observe the use of the term “pull” rather than “push.” Although it is true that you may attempt to push a heavy, immovable object, the isometric force is always applied by muscles “pulling on the bones”. Another term used for isometric contraction (although isometric is accurate in its literal derivation) is static contraction (McArdle *et al.*, 1991; Fox *et al.*, 1993; Corbin & Lindsey, 1994; Foss & Keteyian, 1998; Kroemer *et al.*, 1999; Heyward, 2006; Powers & Howley, 2007).

2.2.1.3. Eccentric contraction

Eccentric contraction refers to the lengthening of a muscle during contraction (i.e., during the development of active tension) (Saladin, 2007). It was mentioned earlier that eccentric contractions are also classified as isotonic contractions, because the muscle is changing in length (lengthening). A good example of an eccentric action is as follows: flexing your elbow, have someone try to extend your forearm by pulling down on your wrist. At the same time, resist the pull by attempting to flex your elbow. As your forearm is extended, the elbow flexor muscles will lengthen while contracting. This, by definition, is an eccentric contraction. Eccentric contractions are used in resisting gravity, such as walking down a hill or down steps (McArdle *et al.*, 1991; Fox *et al.*, 1993; Corbin & Lindsey, 1994; Plowman & Smith, 1997; Foss & Keteyian, 1998; Kroemer *et al.*, 1999; Vander *et al.*, 2001; Martini, 2006; Heyward, 2006).

2.2.1.4. Isokinetic contraction

During an isokinetic contraction, the tension developed by the muscle as it shortens at constant (iso) speed (kinetic) is maximal at all joint angles over the full range of motion (McArdle *et al.*, 1991; Fox *et al.*, 1993; Corbin & Lindsey, 1994; Plowman & Smith, 1997; Foss & Keteyian, 1998; Powers & Howley, 2007). Such contractions are common during sports performances such as the arm stroke during freestyle swimming. The application of full tension during sports performances or laboratory testing is, of course, dependent on the motivation of the performer (Fox *et al.*, 1993; Foss & Keteyian, 1998). Machines that regulate movement velocity and resistance are usually used during isokinetic exercise and / or testing (Corbin & Lindsey, 1994; McArdle *et al.*, 1996; Powers & Howley, 2001; Powers & Howley, 2007).

2.2.2. Muscular endurance

Corbin and Lindsey (1994) and Hough *et al.* (2001) describe muscular endurance as the capacity of a skeletal muscle, or group of muscles, to continue contracting over a long period of time. It can also be defined as the ability to perform repetitive muscular contractions against some resistance (Arnheim & Prentice, 1993; Foss & Keteyian, 1998; Powers & Howley, 2001). According to Heyward (2006), muscular endurance is the ability of a muscle group to exert submaximal force for extended periods. As with strength, there are four kinds of local muscular endurance, depending on which of the four types of contraction are used. Local muscular endurance is usually defined as the ability or capacity of a muscle group to perform repeated contractions (isotonic, isokinetic, or eccentric) against a load, or to sustain a contraction (isometric) for an extended period of time (Fox *et al.*, 1993; Foss & Keteyian, 1998; Heyward, 2006).

Dynamic endurance tests may be of the absolute or fixed load type, where all subjects are required to lift a common amount of weight at a set cadence until they fatigue and can no longer keep up the pace. This is in contrast to relative load endurance tests, where subjects are assigned a fixed percentage of their maximal strength, say 20% to 50% of 1RM, or of peak isometric tension. They are then timed for their ability to endure a given lifting cadence in dynamic tests, or to sustain a predetermined level of static force in isometric tests. Muscular endurance may also be defined as the opposite of muscular fatigue (i.e., a muscle that fatigues rapidly has a low endurance capacity and vice versa). The factors that contribute to local muscle fatigue will be discussed at a later stage (Fox *et al.*, 1993; Foss & Keteyian, 1998; Heyward, 2006).

2.2.3. Flexibility

Along with strength and endurance, flexibility is also an important component of muscle performance. It can be defined as the range of movement of a specific joint, or group of joints, influenced by the associated bones and bony structures and the physiological characteristics of the muscles, tendons, ligaments, and the various other collagenous tissues surrounding the joint (Arnheim & Prentice, 1993; Corbin & Lindsey, 1994; Hough *et al.*, 2001). Plowman and Smith (1997) defines flexibility as the range of motion in a joint, or series of joints, that reflects the ability of the musculotendon structures to elongate within the physical limits of the joint. Some studies have indicated that an increase in the flexibility of joints tend to decrease the injuries to those joints (Arnheim & Prentice, 1993). Enoka (2002) states that individuals with hypermobile joints, often referred to as being double-jointed or as having lax joints, are characterised by a reduced stiffness of the joint tissues due to enhanced relaxation of the involved muscles.

Plowman and Smith (1997) explain that flexibility and stretching are important for:
(1) everyday living (putting on shoes, reaching the top shelf, etc.);
(2) muscle relaxation;
(3) proper posture;
(4) relief of muscle soreness;
(5) enhancement of physical activity; and
(6) as a means of decreasing the likelihood of injury during physical activity.

Powers and Howley (1994), Plowman and Smith (1997), Foss and Keteyian (1998), and Heyward (2006) describe two basic kinds of flexibility, namely “static” and “dynamic.” The range of motion about a joint is defined as static flexibility. An instrument called a flexometer (a goniometer can also be used) can measure static flexibility most reliably. The reason why it is called “static flexibility” is because there is no joint movement when the measurements are taken (from full extension of the elbow to full flexion of the elbow, for example). Dynamic flexibility is defined as the opposition or resistance of a joint to motion. In other words, it is concerned with the forces that oppose movement over any range rather than the range of motion itself. This type of flexibility is difficult to measure and as such has been given little attention in physical education (Fox *et al.*, 1993; Powers & Howley, 1994; Plowman & Smith, 1997; Foss & Keteyan, 1998; Heyward, 2006).

The so-called soft tissues provide the major limitation to the range of joint movement. The joint capsule and associated connective tissues plus the muscle provide the majority of resistance to flexibility. Because flexibility can be modified through exercise, so also can these soft tissue limitations. The reason for this, at least in part, is related to the elastic nature of some of the tissues (Fox *et al.*, 1993; Foss & Keteyian, 1998; Heyward, 2006). According to Enoka (2002), flexibility can be increased by implementing techniques that improve relaxation of the involved muscles.

2.2.4. Cardiovascular fitness

Corbin and Lindsey (1994) defines cardiovascular fitness (also referred to as “cardiorespiratory fitness” or “cardiovascular endurance”) as the ability of the heart, blood vessels, blood and respiratory system to supply fuel, especially oxygen, to the muscles, and the ability of the muscles to utilise the fuel to allow sustained physical activity. Plowman and Smith (1997) define cardiorespiratory fitness as the ability to deliver and use oxygen under the demands of intensive, prolonged exercise or work. Heyward (2006) defines it as the ability to perform dynamic exercise, involving large muscle groups at moderate to high intensity for prolonged periods. A large part of cardiovascular fitness involves the functioning of the cardiovascular system. This is a continuous system consisting of a pump, a high-pressure distribution circuit, exchange vessels, and a low-pressure collection and return circuit (McArdle *et al.*, 1996). During exercise, cardiac output may increase from a resting value of 5 L/min to a maximal value of 35 L/min in trained athletes (Vander *et al.*, 2001).

In essence, the transport of oxygen throughout the body involves the co-ordinated function of four components; (1) the heart; (2) the lungs; (3) the blood vessels; and (4) the blood. The improvement of cardiovascular fitness through exercise occurs because of the increased capability of each of these four elements in providing necessary oxygen to the working tissues (Arnheim & Prentice, 1993; Corbin & Lindsey, 1994; Vander *et al.*, 2001; Heyward, 2006). Aerobic exercise is the preferred method for improving cardiovascular fitness. It can be defined as an activity for which the body is able to supply adequate oxygen to sustain performance for long periods of time. Aerobic literally means “in the presence of oxygen” (Corbin & Lindsey, 1994).

The greatest rate at which oxygen can be taken in and utilised during exercise is referred to as “maximal oxygen consumption” or “VO_2 max” (Fox *et al.*, 1993; Foss & Keteyian, 1998; Vander *et al.*, 2001; Heyward, 2006). The performance of any activity requires a certain rate of oxygen consumption that is about the same for all persons, depending on the present level of fitness. Generally, the greater the rate or intensity of the performance of an activity, the greater the oxygen consumption will be. Each person’s ability to perform an activity (or to fatigue) is closely related to the amount of oxygen required by that activity and is limited by the maximal rate of oxygen consumption of which a person is capable. It is also true that the percentage of maximum oxygen consumption an activity requires, determines the time a person is capable of performing that activity (higher % = less time) (Arnheim & Prentice, 1993; Fox *et al.*, 1993; Foss & Keteyian, 1998).

The maximal rate at which oxygen can be utilised is a genetically-determined characteristic. A person inherits a certain range of VO_2 max, and the more active a person is, the higher the existing VO_2 max will be within that range. A training programme is capable of increasing VO_2 max to its highest limit within the inherited range. According to Vander *et al.* (2001), prolonged bed rest may decrease VO_2 max by 15 to 25 percent, whereas intense long-term physical training may increase it by a similar amount. VO_2 max is most often presented in terms of the volume of oxygen used relative to body weight per unit of time (ml/kg/min) (Arnheim & Prentice, 1993).

Three factors determine the maximal rate at which oxygen can be utilised: (1) external respiration, involving the ventilatory process, or pulmonary function; (2) gas transport, which is accomplished by the cardiovascular system (i.e., the heart, blood vessels, and blood); and (3) internal respiration, which involves the use of oxygen by the cells to produce energy. Of these three factors, the most limiting is generally the ability to transport oxygen through the system. It is therefore clear that the cardiovascular system is responsible for limiting the overall rate of oxygen consumption. A high VO_2 max within a person's inherited range indicates that all three systems are working well (Arnheim & Prentice, 1993; Foss & Keteyian, 1998; Vander *et al.*, 2001).

It has already been mentioned that cardiovascular fitness refers to the ability of the heart, blood vessels, blood and respiratory system to supply fuel, especially oxygen, to the muscles and the ability of the muscles to utilise the fuel to allow sustained physical activity. Now let's take a closer look at each one of these contributing factors to see how they contribute to cardiovascular fitness:

(1) The heart. The heart is a muscular organ, enclosed in a fibrous sac, the pericardium. The walls of the heart are composed primarily of cardiac muscle cells and are termed the myocardium (Vander *et al.*, 2001; Powers & Howley, 2007). To become stronger, the heart must be exercised like any other muscle in the body. If the heart is exercised regularly, its strength increases; if not, it becomes weaker. Contrary to the belief that strenuous work harms the heart, research has found no evidence that regular, progressive exercise is bad for the normal heart. In fact, the heart muscle will increase in size and power when called upon to extend itself. The increase in size and power allows the heart to pump a greater volume of blood with fewer strokes per minute (Fox *et al.*, 1993; Corbin & Lindsey, 1994; Foss & Keteyian, 1998). The healthy heart is also more efficient in the work that it does. The fit heart can convert about half of its fuel into energy, compared to an automobile engine in good running condition that can only convert about one-fourth of its fuel into energy (Corbin & Lindsey, 1994). McArdle *et al.* (1996) states that the heart of a person with only average physical fitness has a maximum

output of blood in 1 minute that is greater than the fluid output from a household faucet when it is wide open.

(2) The vascular system. Blood containing a high concentration of oxygen is pumped by the left ventricle of the heart through the aorta (a major artery), from where it is carried to the tissues with smaller arteries. Blood flows through a sequence of arteries, to capillaries, to veins. Veins carry the blood containing lesser amounts of oxygen back to the right side of the heart, first to the right atrium and then to the right ventricle. The right ventricle pumps the blood to the lungs. In the lungs, the blood picks up oxygen and carbon dioxide is removed. From the lungs, the oxygenated blood travels back to the heart, first to the left atrium and then to the left ventricle. The process then repeats itself (Corbin & Lindsey, 1994; Martini, 1995; McArdle *et al.*, 1996; Vander *et al.*, 2001).

Healthy arteries are elastic, free of obstruction, and expand to permit the flow of blood. Muscle layers line the arteries and control the size of the arterial opening on the impulse from nerve fibres. Unfit arteries may have a reduced internal diameter (atherosclerosis), because of deposits on the interior of their walls, or they may have hardened, nonelastic walls (arteriosclerosis). Fit arteries are extremely important to good health. The blood in the four chambers of the heart does not directly nourish the heart. Rather, numerous small arteries within the heart muscle provide coronary circulation. Poor coronary circulation precipitated by unhealthy arteries can be the cause of heart disease (Fox *et al.*, 1993; Corbin & Lindsey, 1994; McArdle *et al.*, 1996; Foss & Keteyian, 1998; Vander *et al.*, 2001).

Veins have thinner, less elastic walls than arteries. Also, veins contain small valves to prevent the backward flow of blood. Skeletal muscles assist the return of blood to the heart. The veins are intertwined in the muscle; therefore, when the muscle is contracted, the veins are squeezed, pushing the blood on its way back to the heart. A malfunction of the valves results in a failure to remove used blood at the proper rate. As a result, venous blood pools, especially in the legs, cause a condition known as varicose veins (Fox *et al.*, 1993; Corbin & Lindsey, 1994; McArdle *et al.*, 1996; Foss & Keteyian, 1998; Vander *et al.*, 2001).

Capillaries are the transfer stations where oxygen and fuel are released and waste products, such as CO_2, are removed from the tissues. The veins receive the blood from the capillaries for the return trip to the heart (Fox *et al.*, 1993; Corbin & Lindsey, 1994; McArdle *et al.*, 1996; Foss & Keteyian, 1998; Vander *et al.*, 2001).

(3) The respiratory system and the blood. The process of taking in oxygen (through the mouth and nose) and delivering it to the lungs, where it is picked up by the blood, is called external respiration. It is also referred to as pulmonary respiration (Powers & Howley, 2007). External respiration requires fit lungs, as well as blood with adequate haemoglobin in the red blood cells (erythrocytes). Insufficient oxygen-carrying capacity of the blood is called anaemia (Fox *et al.*, 1993; Corbin & Lindsey, 1994; Foss & Keteyian, 1998; Vander *et al.*, 2001).

Delivering oxygen to the tissues from the blood is called internal respiration, or cellular respiration (Powers & Howley, 2007). Internal respiration requires an adequate number of healthy capillaries. In addition to delivering oxygen to the tissues, these systems remove CO_2. Good cardiovascular fitness requires fitness of both the external and internal respiratory systems (Fox *et al.*, 1993; Corbin & Lindsey, 1994; Foss & Keteyian, 1998; Vander *et al.*, 2001).

(4) The muscle tissue. Once the oxygen is delivered, the muscle tissues must be able to use oxygen to sustain physical performance. Cardiovascular fitness activities rely mostly on ST muscle fibres. These fibres, when trained, undergo changes that make them especially able to use oxygen. Outstanding distance runners often have high amounts of ST fibres and sprinters often have high amounts of FT muscle fibres (Fox *et al.*, 1993; Corbin & Lindsey, 1994; McArdle *et al.*, 1996; Foss & Keteyian, 1998; Vander *et al.*, 2001).

2.2.5. Muscle Fatigue

Muscle fatigue has been defined as a decline in maximal force-generating capacity and as a common response to muscular activity (Foss & Keteyian, 1998; Powers & Howley, 2001). According to Fox (2006), muscle fatigue may be defined as any exercise-induced reduction in the ability of a muscle to generate force or power. Vander *et al.* (2001) states that, when a muscle fibre is repeatedly stimulated, the tension developed by the fiber eventually decreases, even though the stimulation continues. He states that this decline in muscle tension as a result of previous contractile activity is known as muscle fatigue. Muscle fatigue is often quantified as a reduction in the maximum force that a muscle can exert (Enoka, 2002).

A muscle or muscle group may fatigue because of failure of any one or all of the different neuromuscular mechanisms involved in muscular contraction (Fox *et al.*, 1993; Foss & Keteyian, 1998). For example, the failure of a muscle to contract voluntarily could be due to failure of the following:

(1) the motor nerve innervating the muscle fibres within the motor units to transmit nervous impulses;
(2) the neuromuscular junction to relay the nervous impulses from the motor nerve to the muscle fibres;
(3) the contractile mechanism itself to generate a force; or
(4) the central nervous system (i.e., the brain and spinal cord) to initiate and relay nervous impulses to the muscle (Fox *et al.*, 1993; Plowman & Smith, 1997; Foss & Keteyian, 1998; Vander *et al.*, 2001).

Most research concerning local muscular fatigue has focussed on the neuromuscular junction, the contractile mechanism and the central nervous system. The possibility of the motor nerve as the site and cause of fatigue is not very great (Fox *et al.*, 1993; Foss & Keteyian, 1998).

2.2.5.1. Fatigue at the Neuromuscular Junction

This type of fatigue appears to be more common in fast-twitch (FT) motor units and may account, in part, for the greater fatigability of FT fibres compared with ST fibres. Failure of the neuromuscular junction to relay nervous impulses to the muscle fibres is most likely due to a decreased release of the chemical transmitter, acetylcholine, from the nerve ending (McArdle *et al.*, 1991; Fox *et al.*, 1993; Plowman & Smith, 1997; Foss & Keteyian, 1998; Vander *et al.*, 2001).

2.2.5.2. Fatigue within the Contractile Mechanism

Several factors have been implicated in fatigue of the contractile mechanism itself. Some of them are:

(1) *Accumulation of lactic acid*. There is a relationship between intramuscular lactic acid accumulation and a decline in peak tension (a measure of fatigue). FT fibres produce more lactic acid in comparison to ST fibres. This greater ability to form lactic acid might be one contributing factor to the higher anaerobic performance capacity of the FT fibres. As the lactic acid FT:ST ratio within a muscle increases, the peak tension of that muscle will decrease. This may be interpreted to mean that the greater fatigability of FT fibres is related to their greater ability to form lactic acid (Fox *et al.*, 1993; Foss & Keteyian, 1998). The idea that lactic acid accumulation is involved in the fatigue process is further strengthened by the fact that there are at least two physiological mechanisms whereby lactic acid could hinder muscle function. Both mechanisms depend on the effects lactic acid has on intracellular pH or hydrogen ion (H^+) concentration. With increases in lactic acid, H^+ concentration increases and pH decreases. On the one hand, an increase in H^+ concentration hinders the excitation-coupling process by decreasing the amount of Ca^{++} released from the sarcoplasmic reticulum and interfering with the Ca^{++}-troponin binding capacity. On the other hand, an increased H^+ concentration also inhibits the activity of phosphofructokinase, a key enzyme involved in anaerobic glycolysis. Such an inhibition slows glycolysis, thus reducing the availability of ATP for energy (Meyer & Meij, 1992; Fox *et al.*, 1993; McArdle *et al.*, 1996; Foss & Keteyian, 1998; Vander *et al.*, 2001; Martini, 2006).

(2) *Depletion of ATP and PC stores*. Because ATP is the direct source of energy for muscular contraction, and PC is used for its immediate resynthesis, intramuscular depletion of these phosphagens results in fatigue. Studies with humans, however, have been conclusive that exhaustion cannot be attributed to critically-low phosphagen concentrations in muscle (Fox *et al.*, 1993; Foss & Keteyian, 1998). Despite the preceding information, the possibility that ATP and PC might still be involved in the fatigue process cannot be completely dismissed (Meyer & Meij, 1992). It has been suggested that, during contractile activity, the concentration of ATP in the region of the myofibrils might decrease more markedly than in the muscle as a whole. Therefore, ATP could be limited within the contractile mechanism even though there is only a moderate decrease in total muscle ATP content. Another possibility is that the energy yield in the breakdown of ATP, rather than the amount of ATP available, is limiting for muscular contraction. For example, the amount of energy liberated when 1 mole of ATP is broken down to ADP + Pi has been calculated to decrease almost 15%, from 12.9 kilocalories (kcal) at rest to as low as 11.0 kcal after exhaustive exercise. The reason for this decrease might be related in part to large increases in intracellular H^+ ion concentration, primarily due to lactic acid accumulation (Fox *et al.*, 1993; Foss & Keteyian, 1998; Powers & Howley, 2001; Vander *et al.*, 2001; Martini, 2006).

(3) *Depletion of Muscle Glycogen Stores*. During prolonged exercise the muscle glycogen stores within some of the fibres (mainly ST fibres) are nearly completely depleted. It is thought that such severe glycogen depletion is a cause of contractile fatigue (Vander *et al.*, 1990; Fox *et al.*, 1993; McArdle *et al.*, 1996; Foss & Keteyian, 1998; Fox, 2006). This is thought to be true even though plenty of free fatty acids and glucose (from the liver) are still available as fuels to the muscle fibres. A definite cause-and-effect relationship between muscle glycogen depletion and muscular fatigue has not yet been determined (Fox *et al.*, 1993; Foss & Keteyian, 1998).

(4) *Other factors*. Some additional, but less well-understood, factors that may contribute to muscular fatigue are lack of oxygen and inadequate blood flow (McArdle *et al.*, 1991; Meyer & Meij, 1992; Fox *et al.*, 1993; Foss & Keteyian, 1998).

2.2.5.3. The Central Nervous System and Local Muscular Fatigue

As a muscle fatigues, the local disturbances that occur within its internal environment are signalled back to the central nervous system (brain) via sensory nerves. In turn, the brain sends out inhibitory signals to the nerve cells in the motor system, resulting in a declining muscular work output (Fox *et al.*, 1993; Foss & Keteyian, 1998; Vander *et al.*, 2001). During a rest pause, the local disturbances tend to be restored in the muscles, and the fatigue gradually diminishes or disappears. If a diverting activity is performed during a pause period, other signals from the periphery, or from the brain itself, will impinge on the facilitatory areas of the brain. Consequently, facilitatory impulses will be sent to the motor system, leading to better muscular performance, or to faster recovery from fatigue. The local disturbances in the contractile mechanism of the muscle that initiates this series of events are most likely those discussed earlier (i.e., lactic acid accumulation and depletion of ATP + PC and muscle glycogen). These discussions tend to indicate that local muscular fatigue is very complex, having several etiologies, and is not as yet well-understood (Fox *et al.*, 1993; Foss & Keteyian, 1998).

Meyer and Meij (1992) explain that local muscular fatigue can go together with muscle cramps from time to time. A cramp is a painful condition that is caused by a muscle that tetanically (spastically) contracts without the ability to relax completely. It seems that the cause of this is a shortage of ATP. ATP is required for transferring Ca^{++} to the sarcoplasmic reticulum. If this does not happen sufficiently, the accumulation of Ca^{++} causes the actin- and myosin filaments to stay binded and consequently the muscle fibres are unable to relax (Meyer & Meij, 1992). Vander *et al.* (2001) states that, during cramping, nerve action potentials fire at abnormally high rates. They further state that this is probably related to electrolyte imbalances in the extracellular fluid surrounding the muscle and nerve fibres, as well as changes in extracellular osmolarity.

2.3. Job analysis

Without knowledge of the critical physical demands of a job, a therapist is unable to establish an appropriate work rehab programme and, therefore, cannot determine when an injured worker can safely and productively return to work (McKenney, 2000). Arvey (2005) states that the first step in physical ability testing is to assess the physical demands of work through careful job analysis. Information on job demands can be used to devise functional capacity evaluations, or work hardening, and to assess fitness for duty (Halpern *et al.*, 2001). An important question is: “How are job demands assessed?” (Toeppen-Sprigg, 2000).

One of the first things to think about is how one will identify those tasks that will be simulated by the physical assessments. In other words, to determine which physical tasks have to be performed successfully in order to be successful in the specific job and the measurability of these tasks (Shrey & Lacerte, 1997; Fine & Cronshaw, 1999; Bester, 2003).

It is important to remember that a job is performed by a whole person with knowledge, skills and abilities. That being said, one has to have the ability to focus on a rather narrow piece of the job. One has to focus on the tasks being performed in the job to understand the physical demands. The task analysis segment is, however, the most important part of the job analysis process (Toeppen-Sprigg, 2000). Davis and Dotson (1987) give their criteria for the identification of such tasks. The tasks should be:

(a) frequently performed;
(b) critical (i.e. failure to perform such a task is likely to result in destruction of property or loss of life);
(c) non-skill dependent;
(d) objectively measurable (easily standardisable); and they should
(e) consist of truly arduous factors that have the greatest discriminatory power.

It is clear that the focus should fall on methods which have been developed to determine the physical requirements of jobs and on identifying which physical abilities are vital in order to successfully perform the tasks related to these jobs (Bester, 2003). Isernhagen (2000a) points out that employees who perform the job(s) in question are the best resource to use when conducting an analysis. Their participation will provide the opportunity to gather accurate information and to solicit the workers' buy-in to the process, which will help lead to their support of the work injury prevention and disability system. According to Halpern *et al.* (2001), an assessment of the occupational exposure is often obtained from job incumbents or their supervisors. Because this information has a clinical utility in early intervention, it would be of practical value to obtain an assessment of job demands directly from the patient.

A number of methods and approaches that apply to the analysis of jobs and their ability requirements are well-documented. They include:

2.3.1. Questionnaires

An employee questionnaire is an excellent tool to solicit information from workers. A typical questionnaire would be one that requires the workers' input about the physical requirements (walking, standing, lifting, carrying, climbing, etc.). The questionnaires should be completed by a variety of workers (new, old, males, females) so that the information represents a good cross-section of workers (Isernhagen, 2000a). Questionnaire data (typically based on self-report) are advantageous when precision and detail in measurement are not paramount, despite limitations in the methodology (Janowitz *et al.*, 2006).

In a study by Halpern *et al.* (2001), the researchers set out to develop a new comprehensive questionnaire that would be easy to administer in a clinical setting, user-friendly, reliable and valid. Their questionnaire was limited to assessing current job exposure that could be used to discover predictors of disability in the working population. Three standard instruments, the AET (Rohmert & Landau, 1983), the Music study (Wiktorin *et al.*, 1993), and the PLIBEL (Kemmlert, 1995), provided the framework for the questionnaire. All had been validated, could be self-administered or completed by interview techniques, and shared similar questions, as well as rating scales. Their questionnaire consisted of twenty-six items. Five questions on work organisation had nominal (yes / no) scales, and the rest had an ordinal 6-point scale of duration (percent of work time), or a 5-point frequency scale. This questionnaire is very relevant to this thesis and was used as a guideline during the interviews with relevant employees and supervisors.

2.3.2. Interviews

Workers should be interviewed to gather additional information about their jobs. This can be done in addition to the completion of a questionnaire. The people doing the job often know the job best. These people know all the tasks of the job, including the infrequent ones. The workers also know the most difficult tasks. However, the worker may not give an accurate description, especially regarding the weight of objects and push-and-pull forces. Workers tend to overestimate the weight of material and the difficulty of tasks (Shrey & Lacerte, 1997; Isernhagen, 2000a; Bester, 2003).

2.3.3. Job descriptions

Obtain a job description from the employer. Written job descriptions provide an overview of the worker requirements, as well as an understanding of the tasks to be performed and the expectations of the employer (Meier, 1998; Isernhagen, 2000a). Usually, these descriptions do not contain enough detail on which to base an accurate assessment. They may not include some of the infrequent tasks and may not provide weights, heights and the frequencies of repetitive tasks (Shrey & Lacerte, 1997; Bester, 2003).

2.3.4. Videotapes

Obtain a videotape of the job. This will allow the evaluator to become familiar with the job and identify specific issues that will need further assessment during the analysis (Isernhagen, 2000a). If filmed correctly, videotapes can provide the assessment designer with a relatively-complete analysis of a job. This approach is especially useful if accompanied by a written description, or if viewed with either the worker or the worker’s supervisor (Shrey & Lacerte, 1997; Bester, 2003). Videotaping is often also used in ergonomics analysis to capture postures and movements that may be difficult to record with direct observation. Drawbacks include the disruption of work, the cumbersome nature of setting up cameras in workspaces, and the difficulty of following workers who perform non-stationary tasks (Janowitz *et al.*, 2006).

2.3.5. Job-site assessments

A job-site assessment would partially consist of a walk through, which could be described as a tour of the worksite in order to gain an appreciation of the work environment (Isernhagen, 2000a). Essentially, however, the job assessment is an objective, systematic procedure for determining the physical requirements and demands of a specific job, as well as determining the exposure to generic risk factors such as forceful exertions, awkward postures, localised contact stresses, repetitive motions and prolonged activities. Included in the job assessment are the work objectives of the job, the production rate, the equipment and tools used to perform the job, a description of any materials or products that are handled, and the work methods employed. Work methods consist of the weights and forces required to move material and equipment, distances the materials are carried and time duration of any sustained forces and postures. Unlike the mentioned job analysis methods, completing a job assessment requires the actual measurement of any materials that are handled, including the weight and the physical dimensions (Shrey & Lacerte, 1997; Isernhagen, 2000a; Bester, 2003).

2.3.6. Observation

Observing the job being performed is an important part of any analysis. Watching the worker perform each of the work tasks gives the evaluator a real-world understanding of the physical requirements (Isernhagen, 2000a). Observational methods aimed at characterising postures can be effective in dynamic work situations, when it is necessary to assess multiple types of activity. Simple observational checklists are best used for rapid, initial assessments, often dichotomised to a yes / no option. More elaborate observational systems that transcend dichotomous checklists can involve paper and pen notations, or to utilise computer assistance (Janowitz *et al.*, 2006).

Toeppen-Sprigg (2000) adds that, when a functional job analysis (that is valid, accurate, quantitative and comprehensive) is combined with a discussion of the job objectives, essential job functions, equipment used to perform the job, significant worksite measurements and the critical physical demands of the job, it becomes a functional job description that is very useful to the relevant occupational health professionals. An effective functional job analysis should look at the following aspects:

(1) lift and / or carry requirements – floor to waist, waist to shoulder, above shoulder;
(2) push and / or pull;
(3) rotational movements;
(4) static positions – standing, crouching, bending, neck extension;
(5) positional changes – walking, climbing, balancing;
(6) reaching;
(7) grasping and handling;
(8) aerobic requirements; and
(9) environmental conditions (Isernhagen, 1995; Toeppen-Sprigg, 2000; Huyser & Botha, 2007).

Fleishman (1979) places a lot of emphasis on two terms when discussing job analysis and test design. They are “ability” and “skill”. He explains that the term “ability” refers to a more general trait of the individual which is fairly enduring and, in the adult, more difficult to change. Many of these abilities are a product of learning and they develop at different rates, mainly during childhood and adolescence. Some abilities depend more on hereditary factors than on learning factors, but most depend on both to some degree. At a given stage of life they represent traits which the individual brings with him when he begins to learn a new task or job. These abilities are related to performances in a variety of human tasks (Fleishman, 1979; Magill, 1993; Bester, 2003).

The term “skill”, on the other hand, refers to the level of proficiency in a specific task or job. When we talk about proficiency in operating a front-end loader, flying an aeroplane, or playing basketball, we are talking about a specific skill. The assumption is that the skills involved in complex activities, such as jobs, can be described in terms of the more basic abilities. For example, the level of performance a man can attain on a front-end loader may depend on his basic abilities of manual dexterity and motor co-ordination. However, these same basic abilities may be important to proficiency in other skills as well. Thus, manual dexterity is also needed in assembling electrical components, and motor co-ordination is needed to fly an aeroplane. The individual who has a great many highly-developed basic abilities can become proficient at a great variety of specific tasks. The distinction between abilities and skills allows one greater precision in describing, understanding and predicting many complex human performances (Fleishman, 1979; Magill, 1993; Bester, 2003).

2.4. Identifying the test battery for physical ability testing

The planning process in physical assessment depends upon two major issues: what is to be accomplished, and what is the primary deciding factor in achieving these goals (Jones *et al.*, 1989).

When one starts to look at all the research done on job-related physical assessments, for whatever purpose, the immediate realisation is that the options are vast. A major approach to the selection of personnel for physically-demanding jobs focuses on strength requirements. Much of the original work in this area has been spearheaded by Chaffin (1974), Park and Chaffin (1975), Chaffin *et al.* (1977), Chaffin *et al.* (1978), Herrin and Chaffin (1978) and Keyserling *et al.* (1980a). Their approach is based on two assumptions. Firstly, the relationship between the strength requirements of the job and the physical strength of the workers has an impact on the incidence of lower-back (and other) injuries. In other words, injuries are more likely to result to the extent that the jobs require physical strength at or above the capabilities of the workers. The second assumption is that selecting employees with physical strength meeting or exceeding the requirements of the job will result in fewer injuries, less physiological fatigue, and higher levels of job performance. Most of the more recent studies on strength testing tend to support these assumptions (Garg & Moore, 1992; Malan, 1992; Carmean, 1998; Craig *et al.*, 1998). There are, however, also researchers (Newton & Waddell, 1993;

Chavalinitikul *et al.*, 1995; Waddell & Burton, 2001) who do not agree and prefer different approaches to injury prevention.

A pivotal issue is a compatible match between what the worker can do physically and what the job is demanding (Isernhagen, 2001). After years of research, Fleishman (1979) identified nine basic abilities which were found to be useful in describing hundreds of separate physical performances that were researched by him. It is these nine abilities which can be used to evaluate the physical abilities required in new jobs. It is also these nine abilities which provide a basis for selecting tests to measure each of the separate abilities. There are two unique aspects about this approach. Firstly, this assessment approach attempts to measure a wide variety of physical abilities, including endurance (stamina), many types of strength, and measures of flexibility, co-ordination and balance (Jackson, 1994). Secondly, the tests that measure these abilities require little instrumentation or administration training. These features may make Fleishman's approach potentially useful in applied settings (Campion, 1983). Here follows a detailed description of each of the nine ability factors as described by Fleishman (1979) and Magill (1993):

2.4.1. Dynamic strength

This can be defined as the ability to exert muscular force repeatedly or continuously over time. It represents muscular endurance and emphasises the resistance of the muscles to fatigue (Fleishman, 1979; Corbin & Lindsey, 1994; Hough *et al.*, 2001; Heyward, 2006). The common emphasis of tasks involving this ability is on the power of the muscles to propel, support, or move the body repeatedly, or to support it for prolonged periods. It is known, for example, that this ability is involved in pull-ups, push-ups, rope climbing, or other tasks where the body is moved or supported, usually with the arms (Jones & Prien, 1978; Fleishman, 1979).

2.4.2. Trunk strength

This is a second, more limited, dynamic strength factor – specifically in the trunk muscles and particularly the abdominal muscles. For example, tasks such as leg-lifts or sit-ups involve this ability (Jones & Prien, 1978; Fleishman, 1979).

2.4.3. Static strength

In contrast to dynamic strength, which often involves supporting the body's own weight, static strength is the force which an individual can exert against external objects (such as in lifting heavy objects or pulling heavy equipment). It represents the maximum force which an individual can exert, even for a brief period, where the force is exerted up to some maximum effort (Fleishman, 1979; Magill, 1993; Corbin & Lindsey, 1994; Hough *et al.*, 2001). However, resistance to fatigue is not involved, as is the case with dynamic strength. Dynamometer tests, involving the arms, shoulders, back, hands, etc. measure this ability (Jones & Prien, 1978; Fleishman, 1979; Heyward, 2006).

2.4.4. Explosive strength

This is the ability to expend a maximum of energy in one or a series of explosive acts and is also referred to as power. This ability is distinguished from the other strength factors in requiring effective mobilisation of energy for a burst of effort, rather than continuous strain or the exertion of muscles (Fleishman, 1979; Magill, 1993; Corbin & Lindsey, 1994; Hough *et al.*, 2001). Powers and Howley (2007) describe power as the term used to describe how much work is accomplished per unit of time. Examples include broad-jump- and high-jump tasks, as well as short runs, such as the shuttle run and 50-meter dash (Jones & Prien, 1978; Fleishman, 1979).

2.4.5. Extent flexibility

This involves the ability to flex or stretch the trunk and back muscles as far as possible in either a forward, lateral, or backward direction (Fleishman, 1979; Magill, 1993). This would be involved in tasks which require suppleness, as in reaching and stretching activities. A test measuring this ability involves reaching around as far as possible, while remaining in place, to a scale located on a wall (Fleishman, 1979).

2.4.6. Dynamic flexibility

This factor involves the ability to make rapid, repeated flexing movements, in which the resilience of the muscles in recovering from strain or distortion is critical (Fleishman, 1979; Magill, 1993). This would be involved where an individual has to continuously bend up and down in whatever activity he is performing, in contrast to having to stretch a maximum distance as is the case in extent flexibility. A test measuring dynamic flexibility requires repeated bending, twisting and touching (Jones & Prien, 1978; Fleishman, 1979). Heyward (2006) provides a slightly different description of dynamic flexibility, stating that dynamic flexibility is a measure of the rate of torque or resistance developed during stretching throughout the range of motion.

2.4.7. Gross body co-ordination

This is the ability to co-ordinate the simultaneous actions of different parts of the body or body limbs while the body is in movement. This ability has often been called agility (Fleishman, 1979; Magill, 1993; Corbin & Lindsey, 1994; Hough *et al.*, 2001). A test measuring this ability is called “cable jump” and requires the individual to grasp a short cable with both hands in front of him and then to jump over this cable, without releasing it, in a series of trials (Jones & Prien, 1978; Fleishman, 1979).

2.4.8. Balance or equilibrium

This is the ability of an individual to maintain his equilibrium despite forces pulling him off balance. In other words, the capacity to remain stable while the body’s base of support is reduced or changed (Fleishman, 1979; Magill, 1993; Hough *et al.*, 2001). This ability is used, for instance, in walking on narrow surfaces or ledges. A test measuring this ability requires the individual to stand with one foot on a narrow rail, with eyes closed, for as long as possible (Jones & Prien, 1978; Fleishman, 1979).

2.4.9. Stamina

Stamina is also referred to as “cardio-vascular endurance,” since it involves the capacity to continue maximum effort requiring prolonged exertion over time (Fleishman, 1979;

Magill, 1993; Hough *et al.*, 2001). The heart muscle and cardiovascular system are heavily involved in this ability (Heyward, 2006). This can be measured by longer-running tasks where the minimum distance is around 600 meters, but it is better measured by longer tasks, such as the mile run. Performance in such tasks correlates with physiological measures, such as maximum oxygen absorption into the bloodstream (Jones & Prien, 1978; Fleishman, 1979).

These nine abilities serve as a good base when analysing tasks or jobs for physical ability requirements and for establishing appropriate test batteries. It is, however, important to see each job or task as a unique situation with unique requirements and to make the necessary adjustments in order to ensure the validity of the test battery. The idea is to always bring these nine factors into consideration whenever a comprehensive evaluation of physical proficiency is being done, and not to use it as the be all and end all (Fleishman, 1979).

A number of methods for measuring strength have been developed to allow the matching of muscular capabilities of workers with the force requirements of a particular job (De Vries, 1986; Karwowski & Mital, 1986; Heyward, 1991; Newton & Waddell, 1993; Alaranta *et al.*, 1994; Shrey & Lacerte, 1997). It is also widely accepted that such testing is vital and can be carried out safely, reliably and easily (Kraus, 1967; Caldwell *et al.*, 1974; Chaffin, 1975; Chaffin *et al.*, 1977; Garg *et al.*, 1980; Keyserling *et al.*, 1980b; Mital & Ayoub, 1980; Pytel & Kamon, 1981; Kamon *et al.*, 1982; Mital & Manivasagan, 1982; Kroemer, 1983; Griffin *et al.*, 1984; Mital, 1984; Mital & Manivasagan, 1984; Kroemer, 1985; Mital *et al.*, 1985; Karwowski & Mital, 1986; Fox *et al.*, 1993; Alaranta *et al.*, 1994; Shrey & Lacerte, 1997; Bester, 2003). These measurements can also be successfully used to determine the maximum permissible and maximum acceptable levels of loads that can be lifted safely in the vertical, horizontal or transverse planes (Kamon *et al.*, 1982; Mital & Karwowski, 1985).

De Vries (1986), Corbin and Lindsey (1994), Foss and Keteyian (1998), Heyward (2006), and Saladin (2007) all state that, in a physiological sense, there are generally four ways in which the contractile elements of muscle can produce force through the various bony levers available in the human body. They are (1) isometric contraction (static contraction); (2) concentric isotonic contraction (shortening); (3) eccentric isotonic contraction (lengthening); and (4) isokinetic contraction (with constant angular velocity of the limb segment). Each of these types of muscle contraction can be used for both measurement and training purposes. It is, however, important to note that controlled studies have shown no significant correlation between isotonic (dynamic) and isometric (static) measurements of strength gains (De Vries, 1986; Karwowski & Mital, 1986).

The usual procedure followed when implementing strength tests is to determine the strength requirements of the job, either through direct measurement or biomechanical analyses, and then to simulate the muscle movements required in the strength-demanding tasks in a preemployment screening program (Campion, 1983; Malan, 1992). Although it is advisable that the strength being measured in the screening test is similar to that as required on the job, strength in one muscle group can show high correlation with strength in other muscle groups (Fleishman, 1964; Campion, 1983).

2.4.10. Approaches to strength testing

A variety of methods are available for the assessment of human strength. The techniques utilise one of three categories of muscle contractions: isometric, isotonic or isokinetic. Isometric muscle contractions are static and involve no movement. Isotonic muscle contractions are dynamic and do involve movement of the limb. Isokinetic exercise also involves movement, but the speed and sometimes the displacement of the movement is controlled or held constant (Campion, 1983; Shrey & Lacerte, 1997; Krüger & Jansen van Vuuren, 1998). Luk *et al.* (2003) suggests that isometric and isokinetic work modes should be used to evaluate lifting strength. Schonstein and Kenny (2001) also mentions that isokinetic equipment can be used to measure work capacity.

Krüger and Jansen van Vuuren (1998) give a good summary of the advantages and disadvantages associated with the three major types of strength testing (isometric-, isotonic- and isokinetic strength testing). See table 2.1 for this information. Also provided in table 2.1 are a few examples of testing devices that can be used when administering these tests.

Table 2.1: Strength testing: Advantages, Disadvantages and Devices:

Type of strength testing	**Advantages**	**Disadvantages**	**Devices used**
Isometric	(1) Minimum apparatus required. (2) Tests can be administered in the laboratory or in the field. (3) Easy to ensure good stabilisation of subject during testing. (4) Produces less systemic exhaustion when compared to isotonic and isokinetic testing. (5) Preferred strength tests when painful joints are a problem. (6) Helps with the differentiation between contractile and non-contractile tissue pathology.	(1) Tests are not specific enough to determine the changes due to an isotonic- or isokinetic exercise programme. (2) Difficult to make an objective judgement of the physical effort put in by the subject. (3) Can not measure power due to zero speed. (4) Tests reflect angle-specific strength. (5) Tests are associated with the Valsalva manoeuvre.	(1) Dynamometers (e.g. grip-strength dynamometer) (McArdle *et al.*, 1996; Krüger & Jansen van Vuuren, 1998; Erasmus, 1999; Powers & Howley, 2001; Heyward, 2006; Powers & Howley, 2007). (2) Cable tensiometry (McArdle *et al.*, 1991; McArdle *et al.*, 1996; Powers & Howley, 2001; Heyward, 2006). (3) Load cells (Heyward, 2006)

Isotonic	(1) Produces objective documentation of test results. (2) Tests can be administered in the laboratory or in the field.	(1) The subject might have to be trained in a certain movement. (2) The use of momentum during execution might lead to injuries.	(1) Gymnasium apparatus (e.g. 1-RM bench press) (McArdle *et al.*, 1991; McArdle *et al.*, 1996; Krüger & Jansen van Vuuren, 1998; Powers & Howley, 2001; Heyward, 2006; Powers & Howley, 2007).
Isokinetic	(1) Produces objective documentation of test results. (2) Results indicate strength differences and muscle imbalance. (3) Maximum strength can be produced in all phases of the movement. (4) Test results are accurate and repeatable.	(1) Tests take up a lot of time, especially when testing both limbs. (2) Tests require an on-the-spot calibration system, including weight and time. (3) Tests can not be administered in the field. (4) Tests could lead to severe increases in heart rate and blood pressure. (5) Tests depend on the motivation level of the subject. (6) Apparatus is very expensive. (7) The subject might have to be trained in a certain movement.	(1) Electromechanical apparatus (e.g. Cybex Norm) (McArdle *et al.*, 1991; McArdle *et al.*, 1996; Krüger & Jansen van Vuuren, 1998; Powers & Howley, 2001; Heyward, 2006; Powers & Howley, 2007).

Let us now take a closer look at the strength-testing devices that has been mentioned, namely dynamometry, cable tensiometry, one-repetition maximum and electromechanical apparatus.

2.4.10.1. Dynamometry

Handgrip- and back-and-leg-lift dynamometers are mostly used for isometric strength measurement. Both devices operate on the principle of compression. When an external force is applied to the dynamometer, a steel spring is compressed and moves a pointer. By knowing how much force is required to move the pointer a particular distance, one can then determine exactly how much external "static" force has been applied to the dynamometer (McArdle *et al.*, 1991; McArdle *et al.*, 1996; Krüger & Jansen van Vuuren, 1998; Erasmus, 1999; Powers & Howley, 2001; Heyward, 2006).

2.4.10.2. Cable tensiometry

A tensiometer consists of a cable and a riser. As the force on the cable is increased (by a leg extension movement, for example), the riser over which the cable passes is depressed. This deflects the pointer and indicates the subject's strength score for that particular movement. This instrument measures muscular force during a static or isometric contraction where there is essentially no change in the muscle's external length. The tensiometer is lightweight, portable, durable, easy to use, and has the advantage of versatility for recording force measurements at virtually all angles in the range of motion of a specific joint (McArdle *et al.*, 1991; McArdle *et al.*, 1996; Powers & Howley, 2001; Heyward, 2006).

2.4.10.3. One-repetition maximum (1-RM)

This is a dynamic method of measuring muscular strength. It refers to the maximum amount of weight lifted in one maximal effort with correct form during the performance of a predetermined weight-lifting exercise. To test 1-RM for any particular muscle group or groups (such as forearm flexors or leg extensors, for example), a suitable starting weight is selected close to, but below the subject's maximum lifting capacity. If one repetition is completed, weight is added to the exercise device until maximum lift capacity is achieved. Depending on the muscle group evaluated, the weight increments are usually 1, 2 or 5 kg during the period of measurement (McArdle *et al.*, 1991; McArdle *et al.*, 1996; Krüger & Jansen van Vuuren, 1998; Powers & Howley, 2001; Heyward, 2006).

2.4.10.4. Electromechanical apparatus

The emergence of microprocessor technology has made possible a rapid way to quantify accurately the muscular forces generated during a variety of movements. Sensitive instruments are currently available to measure force, acceleration and velocity of body segments in various movement patterns. An isokinetic dynamometer is an electromechanical instrument that contains a speed-controlling mechanism that accelerates to a preset speed when any force is applied. Once this constant speed is attained, the isokinetic loading mechanism accommodates automatically to provide a counterforce in relation to the force generated by the muscle. Thus, maximum force (or any percentage of maximum effort) can be applied during all phases of the movement at a constant velocity. Instantaneous results are available on a connected computer (McArdle *et al.*, 1991; McArdle *et al.*, 1996; Krüger & Jansen van Vuuren, 1998; Powers & Howley, 2001; Heyward, 2006).

Now that the different types of strength measurements and their advantages and disadvantages have been described, let’s take a look at some important considerations when administering a strength test. The following considerations are important when individuals are tested for “strength”, whether by dynamometry, cable tensiometry, 1-RM, or computer-assisted methods. This will ensure that all subjects are treated equally so that fair comparisons can be made (McArdle *et al.*, 1991; McArdle *et al.*, 1996):

(1) standardised instructions should be given prior to testing;
(2) if a warm-up is given, it should be uniform in duration and intensity;
(3) the subject must have adequate practice prior to the actual test to minimise a “learning” component that could compromise initial results;

(4) a minimum number of trials (repetitions) should be determined before the testing in order to establish a criterion score. A single score is usually less reliable than an average of several scores;
(5) care must be taken to ensure that the angle of measurement on the limb or the test device is consistent among subjects;
(6) select tests that result in known reliability of measurement; and
(7) be prepared to consider individual differences in such factors as body size and composition when evaluating strength scores between individuals and groups (McArdle *et al.*, 1991; McArdle *et al.*, 1996).

Many efforts at assessing human strength focus on static (isometric) strength (Schonstein & Kenny; 2001; Luk *et al.*, 2003). This is because the measurement of dynamic strength is more complicated. The body movements are difficult to control or assess, and thus there is a greater potential for error and injury. It is also not always practical to assess dynamic strength, as it can be time-consuming and difficult to administer outside of the laboratory. Therefore, some argue that it may be better to focus only on static strength, because it can more easily be measured by practical, standardised methods. This method of assessment is also relatively simple, quick, and inexpensive to administer (Chaffin, 1975; Shrey & Lacerte, 1997).

In terms of specific methodology, the techniques proposed by Chaffin (1975) in his ergonomic guide for the assessment of static strength may be useful. He reviews four factors that are known to influence a given strength assessment:
(1) the instructions given;
(2) the duration of the measurement;
(3) the posture of the individual during the test; and
(4) the rest allowed between trials.

In his guide, Chaffin (1975) makes recommendations concerning each of these factors and discusses many of the available measurement techniques (Shrey & Lacerte, 1997). Unfortunately, static strength is not perfectly correlated with dynamic strength, and much care must be taken when using tests of static strength to determine dynamic strength (Garg *et al.*, 1980; Shrey & Lacerte, 1997). As a result, even with the difficulties in assessing or controlling movement, many people do use dynamic strength assessment techniques or isokinetic devices in order to measure strength (Pytel & Kamon, 1981). It might also be argued that dynamic muscle movements more closely approximate the types of movements required on most jobs. Hogan *et al.* (1980) contains a list of sources of both dynamic and static strength tests for various muscle groups.

Most studies found that one or two physical ability measures (e.g. arm strength) could adequately predict physical work capacity. However, a strong argument can be made to include additional predictors, even if they do not add substantially to the validity. One reason is that multiple predictors may result in a more reliable battery. But perhaps a more important reason is that using multiple predictors may enhance the content validity of the selection system (Campion, 1983). Most physically-demanding jobs probably require some amount of both strength and endurance, thus measures of both should be included in the predictor set (Hough *et al.*, 2001). Documenting both content and criterion-related validity may be a wise strategy, especially given the potential adverse impact of physical abilities selection systems (Campion, 1983; Jackson, 1994).

It is clear that there are a number of very important considerations as far as test battery selection is concerned. Literature reports a number of criteria when selecting a test battery for physical ability testing. These include that:

(1) it should meet all the legal requirements (Meier, 1998);
(2) it should correspond with the critical physical requirements of the job (Malan, 1992; Meier, 1998; Harley & James, 2006);
(3) it should give a clear indication of the person’s physical abilities to perform the critical physical requirements of the job (Meier, 1998);
(4) it should be cost effective and easy to implement (Meier, 1998; Janowitz *et al.*, 2006);
(5) it should be appropriate for use in settings where confidentiality and privacy demand is critical (Janowitz *et al.*, 2006);

(6) it should be adaptable to heterogeneous environments / jobs (Janowitz *et al.*, 2006);
(7) it should be as unintrusive as possible (Janowitz *et al.*, 2006);
(8) it should be objective and quantitative (Bester & Krüger, 2004);
(9) it should be valid and reliable (Shrey & Lacerte, 1997; Bester & Krüger, 2004);
(10) it should test the critical movements and exertions as closely as possible (Bester & Krüger, 2004); and
(11) it should assess a wide variety of physical abilities (Malan, 1992).

Functional capacity evaluation, or FCE, is a common term in "measurement of work capacity" literature (Johnson & Miller, 2001; Lyth, 2001; Schonstein & Kenny, 2001; Tuckwell *et al.*, 2002; Hofmann & Kielblock, 2007; Legge & Burgess-Limerick, 2007). The aim of FCE is to measure an individual's physical capacities and functional capabilities (Lyth, 2001). FCEs also allow the health practitioner to predict the timing of return to work (following injury or illness) and the level of physical work a worker can safely sustain upon his or her return to work (Johnson & Miller, 2001; Schonstein & Kenny, 2001). Tuckwell *et al.* (2002) describes an FCE as a systematic, comprehensive, objective series of dynamic tests designed to measure an individual's abilities or performance in work-related tasks. It is important to note that the term FCE is primarily implemented for the purpose of disability management. This differs from physical ability testing in as far as the latter has a number of additional uses, including pre-employment testing and job accommodation.

2.5. Calculating minimum physical requirements (MPR), or "cut-off scores"

Cut-off scores are often used in conjunction with strength tests and they are usually set to approximate the maximum (or near-maximum) requirements of the job. In other words, the minimum physical ability that an individual should possess. Biddle and Sill (1999) discusses a number of approaches to determining a cut-off score. The cut-off score is the test score that an applicant must obtain to be considered for a job (Jackson, 1994; Biddle and Sill, 1999; Bester, 2003). It is critical that persons being employed not only show the ability to do the job safely and effectively, but also have the ability to be trained further, especially in occupations such as the police force, where further training is of the utmost importance (Meier, 1998).

Biddle and Sill (1999) mentions that a variety of practices are followed when developing pass / fail cut-offs for physical ability tests. The following methods are commonly used:
(1) the modified Angoff (Subject matter experts firstly undergo the physical ability tests. After this they complete surveys and provide their opinions on the test scores that best represents where a minimally-qualified applicant would score. The subject-matter expert opinions are then averaged into a pass / fail cut-off);
(2) norm-referenced (Cut-off scores should normally be set so as to be reasonable and consistent with normal expectations of acceptable proficiency within the workforce. Evaluating subject matter expert performance on a physical ability test is an effective way to determine what constitutes "normal expectations of acceptable proficiency"); and
(3) criterion-referenced (Criteria usually include peer- or supervisory ratings on incumbent performance on the physical aspects of the job. It is important to note that the scales used to obtain criterion ratings should not exceed the range of human judgement. The point at which the physical ability test data intersects with the marginal performance rating can be used to establish the pass / fail cut-off).

Using a combination of one or more of the methods is usually the appropriate approach for determining the cut-off that best represents the level required for successful job performance (Biddle & Sill, 1999).

Bester and Krüger (2004) describe their method of calculating MPR for a physically-demanding job in an electricity supply company, using a battery of work simulation tests. The first step was to calculate the mean, median, mode and standard deviation (the measures of central tendency) for each test, based on the data gathered from the target population. The next step was to gather information from people who are experts in the kind of work being performed by the target group. Supervisors were asked to provide the name of an employee in each of their technical service centres whom they perceived to be a good "cut-off" for performing the applicable job. The idea was to compare the practically-based feedback from these experts with the scientifically-based statistical values mentioned earlier (the measures of central tendency). The test data of these "cut-off employees" were used to calculate a subjective cut-off score for each test. These subjective cut-off scores were then compared to the measures of central tendency. It became clear that the average subjective scores obtained from the supervisor feedback, were very closely related to the mean and the median of each test. The MPR were calculated by making use of the average of these three measurements, therefore combining both the practical experience of the supervisors and the scientifically-based measures.

The consensus in the professional literature is that there is no single method of determining a cut score that is optimal in all situations. The decision of where to set a cut score for a physical ability test should be a business decision that depends not only upon the available labour pool, but also other factors, such as desired levels of work productivity, worker safety and level of adverse impact (Jackson, 1994). A certain level of physical strength is required in order to perform certain tasks and an inability to operate heavy tools and handle heavy equipment will not only be dangerous, but it would also make the performance of certain key duties impossible. The same tests would, however, have absolutely no relevance when screening potential office clerks, for example, as physical strength cannot impact on the inherent requirements of the position, nor does a lack of physical strength hold any risk to his / her own or others' health and safety (Botha *et al.*, 1998; Hankey, 2001; Bester, 2003).

The primary concern when setting a cut score is to find the extent to which the test correctly classifies candidates. Furthermore, the cut score should be based on a rational process and valid selection system that is flexible and meets the needs of the organisation. Jackson (1994) offers the following recommendations for developing cut scores:

(1) the cut score should be based upon the results of the job analysis;
(2) the validity and job-relatedness of the testing procedures are crucial;

(3) the cut score should be sufficiently high to ensure minimally-accepted job performance;
(4) the performance level associated with a cut score should be consistent with the normal expectations of acceptable proficiency within the workforce; and
(5) a warranted concern is the utility of the decision process (utility in this context concerns the cost savings for eliminating unqualified applicants).

It is important to note that the onus is on the employer to disprove unfair discrimination. Occupational health practitioners / professionals should therefore take care to ensure the relevance of any and all evaluations to the inherent requirements of the job. Inherent requirements of the job refer to the following:

- requirements of the task – aspects may include work demands, work environment, social aspects, temporal aspects (type of shift work) and ergonomic aspects;
- requirements of the job – factors which may influence work performance directly or indirectly include age, sex, body size, attitude, motivation, workload, fatigue and type of work; and
- physical demands – strength, climbing, balancing, stooping, kneeling, crouching, reaching, handling, sight, speech and hearing (Botha *et al.*, 1998).

Occupational health professionals have a significant role to play in the selection of suitable employees (Hogan & Quigley, 1986; Botha *et al.*, 1998; Bester, 2003). It is, however, important to note that this can have serious legal implications and the Labour Relations Act looks closely at this. In terms of this thesis, the following items in the Labour Relations Act No. 66 of 1995 are applicable:

- Schedule 7, item 2(1)(a) of the Act determines that an unfair labour practice may also result from any unfair discrimination on grounds which include disability.
- Schedule 7, item 2(2)(b) of the Act allows an employer to implement policies and practices designed to achieve adequate protection and advancement of people previously disadvantaged by unfair discrimination.

- Schedule 7, item 2(2)(a) of the Act determines that any discrimination based on the inherent requirements for a particular job does not constitute unfair discrimination (Labour Relations Act 66, 1995; Botha *et al.*, 1998).

In addition to this, the Employment Equity Act, No. 55 of 1998, also contains a number of provisions designed to prevent unfair discrimination against employees on the basis of their medical condition:

- Section 5(1) of the Act echoes the Labour Relations Act in its prohibition of unfair discrimination on grounds that include disability.
- Section 5(2) of the Act also qualifies unfair discrimination (as do the Labour Relations Act) to exclude positive measure consistent with the purpose of the Bill, as well as discrimination based on the inherent requirement of a job.
- Section 5(4) of the Act prohibits the medical testing of an employee for any medical condition unless: (1) legislation requires or permits the testing; or (2) it is justifiable to do so in light of medical facts, employment conditions, the fair distribution of employee benefits or the inherent requirements of a job (Botha *et al.*, 1998; Employment Equity Act 55, 1998).

The applicable question for any occupational health professional to ask is: “When will a pre-placement assessment give rise to unfair discrimination?”

Any medical assessment in contravention of Section 5(4) of the Employment Equity Act will obviously substantiate a claim of unfair discrimination. The issue may be even more problematic where an assessment is in fact admissible in terms of the said Act. In this regard it is important to bear in mind that discrimination, based on the inherent requirement of a particular job, does not constitute unfair discrimination. By implication, unfair discrimination (from a medical or health point of view) will therefore exist where an applicant, on medical grounds, is found to be unsuitable for a particular position while his particular disability or affliction does not significantly diminish the applicant’s ability to perform the work. In other words, where the applicant’s medical condition does not impact on any inherent requirement for the specific job and the applicant is nevertheless unsuccessful as a direct result of his medical condition, the employer's failure to appoint the applicant will constitute an act of unfair discrimination (Grogan, 1997; Botha *et al.*, 1998; Bester, 2003).

It is imperative for the employer to be able to conclusively show, not only that the assessment was in compliance with the Employment Equity Act, but also that the decision not to appoint an applicant was either: (1) not based on the applicant's medical condition at all; or (2) based on an inherent requirement of the job that the applicant is unable to perform, due to a specific medical impairment or physical inability (Grogan, 1997; Botha *et al.*, 1998; Bester, 2003).

Now that some light has been shed on pre-placement assessment and the legislation involved, let us take a look at pre-placement assessment in practice and the rationale behind it.

The primary purpose of a pre-placement assessment is to ensure that the individual is fit to perform the task involved effectively and without risk to his / her own health and safety, or that of others. It is essential that the occupational health practitioner / professional must have an intimate understanding of the job in question. For the applicant to be considered for employment, it should be possible to make an educated judgement on whether he / she is:

(1) capable of performing the work without any ill effects;
(2) capable of performing the work, but with reduced efficiency and / or effectiveness;
(3) capable of performing the work, although this may adversely effect his / her medical condition;
(4) capable of performing the work, but not without unacceptable risk to the health and safety of himself / herself, other workers, or the community; or
(5) physically or mentally incapable of performing the work in question (Cox *et al.*, 1995; Botha *et al.*, 1998).

All pre-placement tests and evaluations should be directly related to the inherent requirements of the job, or at least be justifiable in terms of other valid considerations. The bottom line is that employers should exclusively focus on talent and competency when employing people. This will not only steer clear of possible legal liability, but it will also serve to ensure that potentially productive employees are not unfairly excluded from the labour market. The potential for contribution in this regard by the various occupational health professionals is huge and the importance of their role cannot be overstated (Botha *et al.*, 1998; Hankey, 2001; Bester, 2003).

2.6. Women in physically-demanding positions

2.6.1. The international trend

In the United States of America, women have, for a number of years now, been applying for and entering a wide variety of positions which require extensive physical exertion in building trades, transportation, industry, and other traditionally male-dominated jobs (Wardle, 1976; Kelsh & Sahl, 1996). According to Savinainen *et al.* (2004), the proportion of workers in physical work has decreased among men, but among women it increased between 1970 and 1993. Smith and Mustard (2004) reports that the number of females working as a percentage of the total workforce rose rapidly in Ontario (the province with the largest proportion of Canada's labour force) between 1976 and 1990, then remained relatively steady through the early- to mid-1990s, and then rose again towards the end of the last century. Gallagher (2002) furthermore comments on an article about Chinese women during the Chinese Cultural Revolution, with specific emphasis on the disadvantage that Chinese women face in societies requiring much physical strength, showing that this country is following the international trend of women working in physically-demanding jobs.

With the advent of so many women entering what had been traditionally male-dominated occupations came the development of entry level tests (Washburn & Safrit, 1982; Davis & Dotson, 1987; Bester, 2003). The initial and majority of legal cases concerning pre-employment testing involved racial and ethnic discrimination by paper and pencil cognitive tests (Arvey & Faley, 1988), but with the increasing interest of women seeking physically-demanding jobs, the litigation of cases concerning physical requirements has increased (Washburn & Safrit, 1982; Jackson, 1994). A major source of this gender discrimination litigation has been with public safety jobs, police officer-, fire fighter- and correctional officer jobs (Jackson, 1994).

The American law is clear: if there is adverse impact, the employment practice is open for legal examination, and the employer needs competent evidence showing that the pre-employment test is valid (Arvey & Faley, 1988). In the 1960s, height and weight standards were a condition of employment for many public safety jobs in America, and these standards clearly had an adverse impact on women. The rationale for using measurements like height and weight was that size was related to physical strength and performance in the mentioned line of work depended upon strength. In June 1977, the United States Supreme Court decided on the case between Dothard and Rawlinson. In this most important case, according to Arvey and Faley (1988), a female was refused employment as a correctional-counsellor trainee because she did not meet the minimum height and weight requirements for the job. The defendants argued that the height and weight requirements were job related, because they have a relationship to strength, which is job related. The Supreme Court ruled that if strength is a real job requirement, then a direct measure of strength should have been adopted. This concurs with requirements used in South Africa today, in as far as pre-employment testing is concerned. As mentioned earlier, it is imperative for the employer to be able to conclusively show that the decision not to appoint an applicant was based on an inherent requirement of the job that the applicant is unable to perform due to a specific medical impairment or physical inability (Grogan, 1997; Botha *et al.*, 1998; Bester, 2003).

As a result of women now accounting for a larger percentage of the active, traditionally male-dominated workforce, there are now also more women in occupations that historically have had higher injury rates (Kelsh & Sahl, 1996). Rice *et al.* (2007) states that musculoskeletal injuries among army health care specialist students have been reported to be approximately 24% for men and 24-30% for women. According to

Björkstén *et al.* (2001), it is well known that musculoskeletal problems are common among female industrial workers, especially when they are still unskilled. Another interesting fact is that in Sweden, women were more often granted temporary disability pension than men (Alexanderson *et al.*, 2005). This section will now shift focus onto the occurrence of injuries in female workers, possible causes and sex differences in injury rates.

2.6.2. Female workers and injuries

Studies among postal-, trade-, electric utility- and semiconductor industry workers, as well as among army trainees, have suggested that females are at higher risk for occupational injuries or musculoskeletal problems (Kelsh & Sahl, 1996). If injury rates are different for male and female workers, it is important to determine what factors explain those differences so that training and injury prevention programmes and better work practices can be appropriately designed and implemented. Possible explanations for these differences include the following:

(1) physical capacity differences exist between men and women (Kelsh & Sahl, 1996; Shuster, 2000);
(2) workplace designs and protective equipment are more appropriate for males than females (Kelsh & Sahl, 1996; Shuster, 2000);
(3) women have additional physical and stress demands due to parental and household responsibilities (Kelsh & Sahl, 1996);
(4) improper training in the use of power tools (Shuster, 2000); and
(5) women are more likely to report injuries (Kelsh & Sahl, 1996).

Björkstén *et al.* (2001) reports on a study conducted on a group of 173 Swedish female blue-collar workers, aged between 20 and 45 years. They found that the most frequently-reported musculoskeletal problems were those referred to the neck, shoulders and thoracic spine. Bru *et al.* (1994) made the same findings in an earlier study, through their analysis of the extended Nordic questionnaire. Hansson *et al.* (2000) found that women with repetitive work, especially in industrial jobs, had much higher prevalence of disorders in their necks, shoulders, and wrists / hands. It is also interesting to note that women in physically-heavy work seems to have more diagnosed diseases than women in mixed physical and mental work (Savinainen *et al.*, 2004). Chen and Hendricks (2001) reports that in 1996, African American women aged 16 and older were treated in emergency departments for an estimated 158 335 non-fatal work-related injuries (2.6 out of every 100 full-time equivalents). Of these injuries, 39% occurred in healthcare, 14% in retail trade and 12% in manufacturing. The leading events for injury were physical exertion and contact with objects.

Kelsh and Sahl (1996) examined work-related injury trends to ascertain if female electric utility workers were at higher risk for work-related injuries than their male counterparts in the same occupation, age and job experience categories. Their study included 9 582 female and 26 898 male electric utility workers employed by the Southern California Edison Company during 1980 – 1992. They found elevated rate ratios for female workers, which indicated that they had the higher injury rates and they mention that women appear at higher risk for most types of injury-producing events (in other words "how injury occurred"). As for the part of the body affected, table 2.2 shows very few differences between males and females in terms of the parts of the body most frequently affected. See table 2.2 for the body parts affected, arranged from most common to least common for both males and females.

All in all the work done by Kelsh and Sahl (1996) seems to indicate that men and women who do the same physically-demanding work more or less suffer from the same injuries, or at least that the body parts are more or less affected equally. However, it also seems to be the case that women suffer more injuries (higher injury rate) than their male colleagues. Cherry *et al.* (2001) supports this finding by stating that in most occupations, and overall, women are at greater risk for musculoskeletal conditions than men. Smith and Mustard (2004) furthermore states that women in manual occupations have more than twice the risk of chronic musculoskeletal injuries compared to men. One reason for this may be lack of sufficient physical ability.

Table 2.2: Parts of the body most frequently injured during electric utility work (a comparison between males and females):

Males	**Females**
1. All upper extremities	1. All lower extremities
2. All lower extremities	2. All upper extremities
3. All head and neck	3. Back
4. Back	4. All head and neck
5. Hand / wrist	5. Hand / wrist
6. Knee	6. Knee
7. Ankle	7. Ankle
8. Shoulder	8. Neck
9. Neck	9. Body systems
10. Body systems	10. Shoulder
11. Hip	11. Hip

The physical ability of women (or lack of it) in physically-demanding positions tends to be a very contentious issue. Shuster (2000) investigates females in the male-dominated field of firefighting. It is pointed out that firefighting includes a number of physical stressors, including ineffective physical conditioning, improper training in the use of power tools and ill-fitting personal protective equipment. Suggested proactive solutions to remedy these problems include sensitivity and social skills training, education, stress management, assertiveness training, task-specific physical conditioning, proper training in the use of power tools and the availability of personal protective equipment in sizes to fit women. It is a common belief that women are not equipped to deal with the rigours of this demanding job. Questions of physical strength, endurance, mechanical aptitude, skills and aggression are often raised in this argument. Factors mentioned which may affect a woman’s successful performance on the job include upper body strength, endurance, physical conditioning and the ability to operate power tools.

Shuster (2000) also mentions that the strength of the average women is thought to be approximately 60% of the strength of the average man. Cinque (1990), however, demonstrates that, with the proper physical conditioning, women can attain the level of strength and endurance to pass required physical ability tests. Savinainen *et al.* (2004) highlights the importance of promoting physical capacity to enhance work ability and functional ability in female workers, especially with increasing age. According to Wardle (1976), there is no reason why women cannot do strenuous work. She also correctly predicted that more women could be expected to undertake jobs which they might not previously have considered.

2.7. Ageing workers in physically-demanding positions

The ageing of the population is both a great challenge and a threat for most modern societies all over the world. Ageing affects both the workforce and the retired population (Savinainen *et al.*, 2004). Over recent years, the study of ageing and work has attracted growing attention in scientific literature as a direct consequence of demographic changes in the age structure of the workforce in many industrialised countries (de Zwart *et al.*, 1995; Larson, 2001). US workers, for example, will not only remain in the workforce for more years than expected, they will also be working in organisations that will press them to be more productive. Trying to meet increasing productivity requirements usually contributes to worker injuries, especially amongst middle-aged and older workers (Freeman, 2004).

In the coming decades, demographic, economic and social changes will result in an increased proportion of elderly persons in the workforce in most industrialised countries (de Zwart *et al.*, 1995). Head *et al.* (2006) states that, according to a recent United States Government Accountability Office report, the number of workers over age 55 is projected to increase significantly over the next twenty years, with this demographic group projected to comprise as much as twenty percent of the workforce by 2015. The European Union countries will have the oldest workforce in their histories in the near future (between 2005 and 2015). The mean age of the workforce will rise to over 45 years of age in this period (Savinainen *et al.*, 2004). Larson (2001) estimated that, in the

United States of America, the annual growth rate of workers 55 years of age and older will be 3.7% between 1996 and 2006. She also estimates that, by the year 2030, people aged 65 and older will represent 18% of the population. According to de Zwart *et al.* (1995), the proportion of workers between 45 and 64 years among the population of active age is expected to rise from 32.1% in 1990 to 42.3% in 2020. By contrast, the proportion of the youngest workers, 15 – 24, is expected to decrease from 23.1% in 1990 to 18.4% in 2020. This trend is causing growing interest in the problems of the ageing worker in current employment (de Zwart *et al.*, 1995). For example, demographic information lends powerful evidence that, as workers move into their 50s and 60s, they become more susceptible to musculoskeletal injuries and unless active prevention is undertaken, the rate of job-related injuries to older workers will grow (Freeman, 2004).

In the literature, a progressive decline in physical work capacity, characterised by diminished aerobic capacity and muscular capacity, has consistently been reported amongst ageing workers (de Zwart *et al.*, 1995). Decline in muscular strength during ageing has been a matter of scientific interest since Quetelet did a pioneering study in 1836. In more recent studies, maximal strength has been reported to reach its peak at the age of 25 – 35 years, to show a slow or imperceptible decrease into the forties and then an accelerated decline (Viitasalo, 1985). In the post-40-year category physical fitness begins to decrease and may impair work capacity and performance, particularly in physically-demanding blue-collar jobs (Louhevaara, 1999). Schibye (2001) reports that aerobic power and muscle strength normally decreases with age. Larson (2001) states that the older worker experiences physical, neurological and sensory changes throughout the normal ageing process. The results may include loss of muscle strength, loss of joint flexibility, decreased reaction time, decreased speed of movement, postural changes, decreased balance control and changes in vision and hearing. For many older individuals, conditions such as arthritis, diabetes or heart disease add to the effects of the normal ageing process. These physical, neurological, sensory and / or pathological changes may affect the older worker’s safety and productivity in the workplace (Coy & Davenport, 1991).

2.7.1. Physical work capacity and ageing

For several decades a large number of scientists have been fascinated by the impact of age upon physical work capacity (Dawson & Hellebrandt, 1945; Bink, 1962; Viitasalo, 1985; Davis & Dotson, 1987; de Zwart *et al.*, 1995; Louhevaara, 1999; Larson, 2001; Schibye *et al.*, 2001; Sluiter, 2006). Physical work capacity may be characterised by the sum of the physical capacities and characteristics. Two relevant aspects in this matter are the aerobic capacity and the muscular capacity. The development of these capacities from childhood until old age has been the subject of numerous studies (de Zwart *et al.*, 1995).

2.7.1.1. Aerobic capacity

Aerobic capacity may be defined as the ability of the cardiorespiratory system to deliver oxygenated blood to metabolising tissues and the ability of these structures to extract oxygen from the delivered blood (Corbin & Lindsey, 1994; Plowman and Smith, 1997). Over recent decades, maximal oxygen consumption (VO_2 max), the highest oxygen uptake the individual can attain during exercise and the product of cardiac output and systemic arteriovenous oxygen difference, has been considered to be a valid measure of overall aerobic capacity (de Zwart *et al.*, 1995). Moreover, VO_2 max is regarded as the best single variable to define age-dependent changes in functional limits of aerobic metabolism and of the cardiorespiratory system (Burdorf, 1992). Schibye *et al.* (2001) reports that lower values of absolute and weight-related VO_2 max are found for elderly groups, when compared with younger groups in the same physically-demanding jobs.

In an earlier investigation about the cross-sectional comparison of VO_2 max over different age classes, evidence was found for a progressive decline in aerobic capacity with ageing. Since then, a linear decline of VO_2 max after the age of 20 – 25 years for both males and females has clearly been established in numerous cross-sectional and longitudinal studies. In cross-sectional studies the reported decline has varied from 0.25 to 0.80 ml/kg/minute per year for men and from 0.25 to 0.40 ml/kg/minute per year for women. Longitudinal studies on the rate of decline of aerobic capacity with ageing, varying from 2.3 to 21 follow-up years, have tended to indicate higher values than those reported in cross-sectional studies. In men, a range decline from 0.56 to an extreme value of 1.62 ml/kg/minute per year has been found, whereas for women declines of between 0.32 and 0.58 ml/kg/minute per year have been reported. A majority of the cross-sectional and longitudinal studies have demonstrated a lower absolute rate of decline in VO_2 max with advancing age in women than in men (de Zwart *et al.*, 1995).

There are clear physiological reasons for the decline in aerobic capacity with increasing age. These reasons include lowering of peak heart rate, lowering of peak rates of ventilation and lower maximal cardiac output, as well as loss of muscle mass (Proctor & Joyner, 1997; Savinainen *et al.*, 2004). According to Savinainen *et al.* (2004), aerobic capacity declines from 0.5 to 1.5% per year.

2.7.1.2. Muscular capacity

Muscle capacity in humans is characterised by muscle strength, muscle contraction speed and muscle endurance. Decreased muscular performance is certainly one of the clearest characteristics of physical ageing (de Zwart *et al.*, 1995; Savinainen *et al.*, 2004), particularly among blue-collar workers (Alaranta *et al.*, 1994). Slowness of movement and weakness are commonly attributed to ageing of skeletal muscles. One of the first scientific research projects on age-related changes in muscle capacity exhibited a 40% loss of maximal muscle force by the age of 65 years. A majority of the ageing-muscle studies have focussed on deterioration of muscle strength only. Although muscle strength tends to be better preserved than aerobic capacity, numerous investigations on age-related changes in isometric and isokinetic muscular strength have reported a decline with age. The annual decline in muscle strength ranges from 0.8% to 5%, depending on the gender, muscle group, type of muscle work and angular velocity (Lindle *et al.*, 1997; Frontera *et al.*, 2000; Samson *et al.*, 2000).

In a comprehensive and classical study, Asmussen and Heebøll-Nielsen (1962) reported an increase in overall isometric strength of 25 different muscle groups from age 20 to 30 years for men. After this, an accelerated decrease took place to age 60 years. For women, a constant strength was found between age 20 and 40 years (80% of men at age 20 – 22 years), which was followed by an accelerated decline to 54% of the isometric strength of men in the 55-year age group. Several cross-sectional and longitudinal studies have reported that both isometric and isokinetic strength increases into the third and fourth decade, then there is a small decline into the fifth or sixth decade and an accelerated decline thereafter (de Zwart *et al.*, 1995). In general, large differences in strength-age relationships can be found between muscle groups and also between men and women. For instance, for muscle groups, differences can be observed in the age at which the highest peak strength level is achieved during life, as well as in the starting point of an age-related decline. Characteristic differences in this respect have been reported between the muscles of the upper extremities and those of the lower extremities (de Zwart *et al.*, 1995). The muscles of the upper extremities appear to exhibit the highest isometric peak strength levels at an earlier age than do those of the lower extremities (Asmussen and Heebøll-Nielsen, 1962; Bemben *et al.*, 1991). A greater rate of decline with age has also been observed for the lower extremities (knee extension strength), compared with the muscle groups of the upper extremities (trunk flexion and extension and elbow flexion strengths) (de Zwart *et al.*, 1995).

In a study by Schibye *et al.* (2001), an expected reduction in the muscle strength among an elderly group was found (average age of young group was 25 years and average age of elderly group was 54 years). The difference of about 10% in handgrip strength between young and elderly workers corresponded to the expected decline of 0.5 – 1% per year, and the difference of about 30 – 45% in shoulder muscle strength corresponded to a 1.5 – 2% decrease per year. No difference was found in the back and abdominal muscle strength between young and elderly workers, which was in contrast to earlier findings (de Zwart *et al.*, 1995).

In addition to muscle strength, muscle contraction speed is also found to slow down with increasing age, indicating a prolonged time to peak tension of muscle force in the elderly. An almost identical pattern in decline of maximal knee extension velocity with age, as compared to maximal isometric and isokinetic strength, has been reported. When correcting for the decrease in maximal strength, the less well-documented voluntary isometric and isokinetic endurance seems to be unaffected in older individuals (de Zwart *et al.*, 1995).

From the above results it may be concluded that the overall decline in muscular capacity up to the age of 65 years seems to be less marked as compared to aerobic capacity. Depending on the muscle group, a decline in muscle strength of 10% - 25% at age 65 (expressed as a percentage of the highest peak value during life) is reported for both sexes (de Zwart *et al.*, 1995).

2.7.2. Physical workload, ageing and health effects

De Zwart *et al.* (1995) illustrate an age-related decrease in physical work capacity in relation to similar work demands for younger and older workers. The discrepancy between a diminishing capacity and stable work demands contributes significantly to a reduction in reserve capacity of the ageing worker. Louhevaara (1999) states that the greater requirements of work output, and the effect of ageing, may considerably increase physical strain and work-related disorders in construction work and vehicle inspection type of blue-collar jobs.

In many production processes, extremely high aerobic workloads are still reported among older workers. In many individual cases the permissible upper tolerance limit of 30 – 35 % of the relative VO_2 for prolonged physical work over an 8-hour workday is amply exceeded, indicating an imbalance between the physical workload and the physical work capacity. A high relative VO_2 refers to low reserve capacity, insufficient for the recovery of short-term physiological responses to work before the beginning of the next work day. With increased age, a slowed recovery of physiological variables directly after exercise and prolonged physical after-effects following a workday are often reported (de Zwart *et al.*, 1995). de Zwart *et al.* (1995) observed a significant decline in the performance of a group of older shift workers (only in the older group), on a physical exercise test, compared to a baseline value one day after working seven consecutive night shifts in a physically-demanding occupation.

Muscle activity can result in the onset of short-term local muscle fatigue. In the case of isometric contractions, for example, the onset of fatigue occurs more rapidly when the relative force exerted crosses a relative threshold of the maximal voluntary contraction. When this decreases with age, the “fatigue threshold” is expected to decline for the ageing worker, influencing the time and frequency with which this specific threshold is exceeded during daily work. For high levels of maximal voluntary contraction, significantly higher values of perceived exertion on sustained isometric contractions have been reported for an older age group, 50 – 59 years, compared with a younger age group of 20 – 29 years. When a muscle is fatigued repeatedly without sufficient recovery after a work day, complaints of long-term or chronic fatigue may arise. This chronic fatigue, in the absence of adequate recovery, can cause or aggravate the development of musculoskeletal disorders (Armstrong *et al.*, 1993). For the ageing worker, a lowered fatigue threshold in combination with a reduced recovery after muscle activity with age is suggested to induce chronic overload of muscles and tendons, inducing musculoskeletal disorders (de Zwart *et al.*, 1995).

Daily overload for many years, in which accumulation of minor local muscle damage and muscle changes, in combination with an age-related deterioration, is expected, might be suggested as the main factor underlying an increase in work-related musculoskeletal complaints with age. These long-term effects can impair capacities to a level at which continuation of the work career is endangered. Disablement as a consequence of these long-term physical health effects is found to be one of the main factors responsible for involuntary drop-out for older workers in industrialised countries before attainment of the retirement age (de Zwart *et al.*, 1995).

2.7.3. Physical workload and its training effect

There have been contradictory results concerning physical workload and its training effect on muscle strength. Some researchers note that physical work has no training effects on physical capacity during ageing, and occupational physical activity over many years may even cause capacity to deteriorate, whereas, on the other hand, researchers found that isometric handgrip strength and weightlifting were good among those with high physical workloads (Savinainen *et al.*, 2004). Torgén *et al.* (1999) suggested that high physical demands on a job had a possible training effect of the upper extremities, especially among men. The results of Shibye *et al.* (2001) also showed a general tendency for greater muscle strength, especially in the shoulder muscles, among men in physical work, but no training effect was found in aerobic power. Alaranta *et al.* (1994) concluded that white-collar workers showed better muscle performance in squatting, sit-ups, arch-ups, and back endurance than blue-collar workers. According to Schibye *et al.* (2001), a rather sharp decline in muscle strength in physical work may imply a combination of an age-related decline of strength and a wearing effect. The type of job may be of great importance for having either a training or a wearing effect on the implicated muscle group (Schibye *et al.*, 2001; Savinainen *et al.*, 2004).

2.8. Occupational injuries in physically-demanding positions

In a 1997 report by the Bureau of Labour Statistics in the United States, 7.4 out of every 100 workers reported an illness or injury associated with their job during 1996. In the same year, cumulative trauma disorders accounted for 64% of the total reported illnesses. Furthermore, the incidence of these disorders increased nearly 500% from 1985 to 1995 (Olson, 1999). For both men and women, injury rates in physically-demanding positions are at least three times higher than those in managerial and professional work (Cherry *et al.*, 2001). The National Institute for Occupational Safety in the USA concluded that there is a credible, scientifically-supported link between certain work factors and cumulative trauma disorders (also referred to as musculoskeletal disorders, occupational overuse syndrome, or repetitive strain injuries). These conditions are associated with repetition, awkward forces, static positions and other workplace exposures that involve the nerves, tendons, muscles, and supporting structures of the body (Olson, 1999).

Occupational injuries are responsible for a significant proportion of worker absenteeism and disability (Swaen *et al.*, 2003). Costs associated with work-related disorders are difficult to measure. Direct costs include medical bills, worker’s compensation premiums and the costs of replacement workers. Indirect costs may include loss of production, total temporary disability costs and litigation (Olson, 1999). For the USA it has been estimated that occupational accidents cost approximately $145 billion in 1992, compared to $26 billion from all occupational illnesses combined. For the same year it was estimated that over 13 million occupational accidents occurred in the United States (Swaen *et al.*, 2003). According to Olson (1999), employers in the United States spent about $2000 for every reported cumulative trauma disorder case in 1996 and these disorders cost employers more than $20 billion for 2.73 million worker's compensation claims in 1993, with indirect costs estimated to have run as high as $100 billion. Helm *et al.* (1999) also reports that worker's compensation costs per claim in the United States increased from an average of $6138 in 1980 to almost $24000 in 1991. Millions of rands / dollars are lost every year due to worker's compensation claims (Lukes & Bratcher, 1990; Malan & Kroon, 1992; Greenberg & Bello, 1996; Cherry *et al.*, 2001; Smith and Mustard, 2004). Lower back pain has traditionally been the most costly industrial injury, with an estimated expense of over 8 billion dollars spent in the United States alone each year (Greenberg & Bello, 1996). According to Capodaglio *et al.* (1997), acute and chronic work-related injuries may be attributed to excessive force demanded by the task (especially by tasks such as lifting, carrying, pushing and pulling), inadequate osteoarticular structures, or insufficient general or local aerobic capacity.

Van Niftrik (1996) claims that South African disability shows a marked variance from the disability patterns in the rest of the world. Globally, the foremost conditions likely to result in a successful disability claim are spinal- and musculoskeletal conditions, accounting for 19% and 15% respectively. This is mirrored amongst South African workers in whom 21.7% of disability claims were due to musculoskeletal conditions. In contrast, the second most common disabling condition in South Africa is mental / psychiatric.

The incidence of occupational accidents varies greatly from occupation to occupation and from industry sector to industry sector (Swaen *et al.*, 2003), but since the injury rates for physically-demanding positions tend to generally be higher than in non-physical occupations, one can safely assume that more occupational accidents occur in physically-demanding positions (Craig *et al.*, 1998). McGwin Junior *et al.* (2005) supports this statement by stating that in their study, the most common mechanisms of injury were falls from height (41%), burns (18%) and electrical injuries (15%). Fractures, burns and closed head injuries were the most common injuries in their study.

Kuneliusa *et al.* (2007) states that work tasks inherent to the automobile manufacturing industry places workers at risk of developing a musculoskeletal injury. According to Cherry *et al.* (2001), musculoskeletal disease is probably the most common occupationally-related cause of ill-health in the UK today. This statement corresponds with Hadler (2005), who estimates that most of the lost time from work each year could be attributed to occupational musculoskeletal injuries. Cherry *et al.* (2001) further states that the national survey of work-related illness estimated in 1995 that over 1 million men and women believed themselves to be suffering from musculoskeletal symptoms caused or made worse by their work. The anatomical regions affected most included (from most common to least common): Hand / wrist / arm, elbow, shoulder, neck / thoracic spine, lumbar spine / trunk, hip / knee, ankle / foot, and other. The distribution of diagnoses within these anatomical regions were as follows:

(1) hand / wrist / arm included nerve entrapment, inflammation in tendon sheath / tendon, Raynaud’s / HAVS / VWF, and pain (pathology ill defined);
(2) elbow included epicondilitis, bursitis, and pain (pathology ill defined);
(3) shoulder included rotator cuff injury, bursitis, and pain (pathology ill defined);
(4) neck / thoracic spine included disc problem, pain (muscular pattern), and pain (pathology ill defined);
(5) lumbar spine / trunk included disc problem, mechanical back pain, and pain (pathology ill defined); and
(6) ankle / foot, included inflammation, and pain (pathology ill defined).

Bester (2003) painted a slightly different picture among physical workers in a South African electricity supply company. In his study, back injuries and back pain was by far the most common orthopaedic problem (64.8% of injuries reported), with shoulder (13.2%), knee (9.9%), hand / wrist (6.6%), ankle / foot (3.3%) and arm injuries (2.2%), following in this order. Waddell and Burton (2001) supports this finding by stating that back pain is one of the most common and difficult occupational health problems. Lower back pain is also the leading cause of work disability in Australia, accounting for 35% of all worker's compensation claims (Schonstein & Kenny, 2001). A study by Olson (1999) reports that nearly 30% of all reported illnesses and injuries in the United States involve disorders of the back. These figures are consistent with international trends and the time lost from work due to lower back pain therefore constitutes a major economic and human cost to the community (Schonstein & Kenny, 2001). Frymoyer *et al.* (1983) reports that lower back pain is the most common disabling musculoskeletal symptom and that patients who report lower back pain to physicians generally have occupations that require more repetitive lifting, pulling and twisting, as well as having more episodes of anxiety and depression and more stressful life events. Lower back pain has also traditionally been the most costly industrial injury (Greenberg & Bello, 1996).

Cherry *et al.* (2001) states that most industrial groups show at least some evidence of higher injury rates for females than for males, and in all groups the upper limb is mainly affected, but in some, particularly public administration and defense, health and social services, and education, disorders of the neck and back are almost equally common. In all groups, lower limb complaints were reported less frequently than those of the upper limb, whether considered by occupation or by industry. Their study focused on the following main industrial groups: mining; food / organic products; petrochemical; metals; automotive; utilities / construction; transport / communication; financial / sales; public administration / defense; education; health / social services; social / personal services; and non-codeable industry.

Compensation claims for traumatic injuries and injuries arising from sprains and strains have decreased considerably in Ontario (Canada) during the ten-year period between 1994 and 2004. This decline was probably due to multiple factors, including safety awareness, safety equipment standards and changes in tasks within occupation groups. Chronic musculoskeletal injuries, however, did not decline at the same rate as traumatic injuries or sprains and strains. This may be because the majority of workplace health and safety campaigns in Ontario have targeted traumatic injuries and sprains and strains, as opposed to musculoskeletal injuries, where the factors associated with increased risk of injury are either harder to change, or not yet known (Smith & Mustard, 2004).

Fabiano *et al.* (2001) conducted a study on trends in the rates of total injuries and fatal accidents in the different sectors of Italian industries during the period 1951 – 1998. The results of their study showed that the ratio between the linked indices of injury frequency and industrial production showed a good correlation over the whole period. A general decline in injuries was found across all sectors, with values ranging from 79.86% in the energy group to 23.32% in the textile group. In analysing fatalities, the trend seemed to be more clearly decreasing than the trend of total injuries, including temporary and permanent disabilities. The high degree of correlation between the injury frequency indices and the industrial production indices show that the factors influencing human safety in industrial activities do not depend on technological developments and that technological changes do not have a universally-preventive effect on injuries and accidents. They found that in some workplaces, advances in technology have been associated with higher injury frequency, in others with risk transfer, in still others with the appearance of new hazards. Intensification of work and production in combination with an increase in overtime also constituted a set of interacting factors that increase risk of injury.

Fabiano *et al.* (2001) also reports that the occupations with the highest rates of accidents in Italy were in the building-, mining- and wood industries. Transport and energy were characterised by the severity of accidental injuries, mostly leading to permanent disability and fatalities. Here follows a summary of the dynamics of the total accidents found by them in the period 1994 to 1998:

(1) fall from one level to another (6.2%);
(2) fall from slipping (6.9%);
(3) fall on same level (7.8%);
(4) injured himself with something (14.4%);
(5) collision with (15.6%);
(6) crushed or pierced by something (20.7%); and

(7) lifting and moving something (3.8%);
(8) lifting something or making an effort to lift something (3.5%);
(9) uncoordinated movement (1.7%);
(10) being in touch with something (3.1%);
(11) pierced himself with something (0.7%);
(12) jammed or caught (0.6%);
(13) bumping against (5.2%);
(14) fallen against (1.9%);
(15) run over by something (0.7%);
(16) fall into opening (0.2%);
(17) accident while driving (5.2%); and
(18) inhalation (0.1%).

A relevant question at this point will be: What are the primary causes of such accidents? According to Swaen *et al.* (2003), their study provides evidence that both fatigue and need for recovery are independent risk factors for being injured in an occupational accident. Legge and Burgess-Limerick (2007) agrees with this by stating that functional assessment, which includes tests of aerobic physical fitness, balance, postural tolerances and material handling tolerances, is increasing in popularity as a preventative tool for controlling sprains and strains in the workplace. Rosenblum and Shankar (2006) states that employees, having been effectively matched to the physical demands of their jobs, may be at significantly-lesser risk of injury and disability from both musculoskeletal and non-musculoskeletal disorders. All these findings are very relevant in the context of this thesis.

McGwin Junior *et al.* (2005) focused their study on the performing of unusual job activities as a risk factor for occupational injuries. They found that a highly-elevated risk of injury was associated with the performance of an unusual job task. Hertz and Emmett (1986), as well as Sorock *et al.* (2004), found significant associations between unusual job tasks and hand injuries. Saari and Lahtela (1981) reported that, in studies of three industries in Finland, more than half the injuries occurred in the course of tasks performed less than once per day. Fabiano *et al.* (2001) states that more consideration should be given to the work environment, to the improvement of the man–machine interface, and to human and organisational factors.

2.9. Job accommodation – what is job accommodation?

The last three sections in this chapter, “women in physically-demanding positions”, “ageing workers in physically-demanding positions”, and “occupational injuries in physically-demanding positions” address three groups of workers that contribute greatly to worker disability and incapacity. The focus now shifts to the management of such cases.

One of the preferred ways of managing the incapacitated worker includes job accommodation, or job modification (Bates, 1999; Burkhauser *et al*., 1999; Lyth, 2001; Halpern, 2003; Unger & Kregel, 2003; Campolieti, 2005). Age plays a major role in this and as the workforce continues to age, organised labour and management will also have to work creatively to redesign jobs, workflow and workpace to accommodate the older workers (Freeman, 2004). Job accommodation can be defined as a pro-active, employer-based approach to:
(a) prevent and limit disability;
(b) provide early intervention for health and disability risk factors; and
(c) foster coordinated disability management, administrative and rehabilitative strategies to promote cost-effective restoration and return to work (Williams & Westmorland, 2002).

According to Huyser and Botha (2007), the concept of job accommodation mainly consists of three different concepts, namely:
(1) adaptation of job outputs;
(2) adjustment of the working environment; and
(3) offering of alternative work.

Halpern (2003) gives the following definition for job accommodation: In the context of return to work, accommodations are interventions that reduce the duration, frequency and / or magnitude of exposure to occupational risk factors. Williams and Westmorland (2002) states that modified work can involve modifications or adjustments of the original job to reduce physical demands or hours worked. It is also critical to emphasize that, during the return-to-work process, the physical demands of work and the functional / physical capacity of the worker must be continually matched (Isernhagen, 2000b).

Disability management is a widely used term in occupational medicine and related literature (van Niftrik, 1996; Helm *et al.*, 1999; Isernhagen, 2000a; Lyth, 2001; Williams & Westmorland, 2001; Unger & Kregel, 2003; Westmorland & Buys, 2004; Campolieti, 2005; Skisak *et al.*, 2006). This relation becomes even clearer when looking at the Westmorland and Buys (2004) definition of disability management. They state that disability management is an employer-based strategy to prevent and manage injury. They also state that disability management embraces a number of key principles:

(1) disability management covers prevention and rehabilitation;
(2) disability management is an employer-directed process using systems at the organisational level;
(3) disability management practice is a collaboration between labour and management to implement programmes to reduce the impact of disability on the workplace;
(4) disability management interventions should be workplace-based; and
(5) disability management requires early intervention in terms of prevention and rehabilitation.

Job accommodation can be an effective instrument in delaying the exit of workers to the disability rolls and prolonging their employment spells (Campolieti, 2005; Sanford & Milchus, 2006; Williams *et al.*, 2006). In the United States it is a requirement, under the Americans with Disabilities Act (ADA), that employers provide reasonable accommodations for qualified individuals with disabilities (Unger & Kregel, 2003; Campolieti, 2005). In Canada, many worker’s compensation boards mandated that employers provide reasonable accommodations to such workers (Campolieti, 2005). The

National Institute of Disability Management and Research in Canada has developed occupational standards for disability management professionals. A National Certification Examination has also been adopted by some members of the European community (Westmorland & Buys, 2004). Botha *et al*. (2000) furthermore clearly states that disability in the South African workplace should be managed by the organisation, and that this should be done effectively, fairly and equitably, and in compliance with the requirements of the relevant acts. The International Labour Organisation recently developed a Code of Practice for Managing Disability in the Workplace. It is evident that disability management is rapidly becoming viewed on a global basis as a primary solution to the economic and human costs of injury and disability in the workplace (Westmorland & Buys, 2004).

Forced job accommodation for individuals with disabilities has been widely debated since the inception of the ADA in the 1990s (Unger & Kregel, 2003; Campolieti, 2005). According to Unger and Kregel (2003), business representatives have claimed that the reasonable accommodation requirements in the United States would harm not only businesses, but also individuals with disabilities. Economists have furthermore attributed the decrease in relative employment for people with disabilities during the post-ADA years to the costs of reasonable accommodations. Fears expressed regarding costs have, however, been unsubstantiated (Blanck, 1997; Helm *et al.*, 1999; Unger & Kregel, 2003; Shartz *et al.*, 2006) and by providing accommodations, employers can actually prolong the employment of disabled workers, or help facilitate their return to work (Allaire *et al.*, 2003; Campolieti, 2005). According to the literature, a number of benefits are associated with such interventions (for both the organisation implementing job accommodations, as well as the affected employee). These benefits are thoroughly discussed in section 2.10 of this literature review.

As for possible risks associated with such interventions, Unger and Kregel (2003) mentions the following concerns or challenges that organisations may face when considering the implementation of job accommodation:

(a) human resource professionals often indicate that they have limited knowledge or experience in supporting employees in need of job accommodation. They are, however, usually viewed as a primary source of assistance in identifying and securing accommodations;
(b) business representatives express uncertainty regarding the ability of first-line supervisors to identify and develop required accommodations;
(c) managers and supervisors within organisations possess limited knowledge of disabilities, accommodations and other related requirements. Subsequently, requests for accommodations may even go unaddressed or be denied; and
(d) research that describes employers' knowledge and utilisations of accommodations, and the extent to which organisations are able to adequately address the support needs of workers, is lacking.

According to Johnson and Miller (2001), the preferred outcome for all parties involved in the return-to-work process is return to work, same employer, and same job. Functional capacity evaluations must therefore be able to effectively match the physical abilities of the worker to the physical requirements of the job. They also state that evaluations that address job specificity can facilitate effective return to work with modified duty. Shamberg (2005) believes that employees, employers and human resource personnel are often in need of professional assistance in determining reasonable accommodations for affected employees.

According to Jansson and Björklund (2007), restrictions in roles and activities often form part of the "return-to-work" process. Halpern (2003) makes mention of a few critical considerations and questions that need to be addressed before any job accommodation process is started, stating that the answers to these questions will affect the cost of the job accommodation process:
(a) Who are the role-players?
(b) What job demands need to be analysed?
(c) What information is useful for all involved in the process?
(d) What potential problems exist in implementing the intervention?

Employers have increasingly demonstrated their capacity to provide accommodations when required. Results from several studies have provided descriptions of the types and costs of accommodations that employers have implemented in the workplace. Overall, these findings indicate that employers appear willing to grant accommodations that are perceived as straightforward, inexpensive, one-time only, not time-consuming, or easy to make, as apposed to requests for accommodations that require a sustained effort, or permanent change in work arrangements (Harlan & Robert, 1998; Unger & Kregel, 2003). According to Berube and Borak (2006) it is, however, critical that the following three key return-to-work medical issues are always considered: (1) risk; (2) capacity; and (3) tolerance. Bates (1999) discusses three case studies that explore various interventions and worksite accommodations:

The first study involved a crane operator with a back injury. The injury was caused by a fall, causing a rupture of his L5-S1 disk, as well as an annular tear at L4-L5, resulting in spinal fusion. At a certain point during his recovery treatment, orthopaedic physicians involved in his treatment released him to work activity with job accommodations. The modifications included removing certain tasks, no lifting over ten pounds, and the allowance for frequent breaks to decrease chances for over-exertion. After nine months from the date of surgery, the subject was released to full duty without restrictions. It is interesting to note that this approach also served as work hardening, which is often used as a final phase of rehabilitation (Bates, 1999).

The second study involved a sandblaster who developed numbness in both wrists. He was diagnosed with tendonitis and demonstrated early carpal tunnel syndrome symptoms, most likely due to specific work tasks. His doctor recommended frequent small breaks and position changes during his workday. In addition, anti-vibration gloves were provided to reduce the stress in the wrists and all blasting tasks were suspended. This subject continued to work, with job accommodations, and thus a lost-time injury was prevented. Cost savings in lost production hours and payments of worker’s compensation benefits were realised. Furthermore, the subject was able to earn his full pay, as well as other normal company benefits during the recovery period (Bates, 1999).

A mechanic was the subject during the final study. His right fourth finger (ring finger) was amputated during an accident at work. After surgery and four days of recovery, the subject returned to limited duty with work restrictions. A vocational and medical evaluation was done to assess work restrictions during medical recovery. His limited duty tasks at first included inventory of parts and ordering of supplies. His normal position requires a heavy level of work with occasional lifting of up to 100 pounds. After three months of therapy and working at the job site, this person was able to lift 27 pounds. After 5 months he was deemed to be a Maximum Medical Improvement, and allowed to return to full work duty. Three main factors contributed to this successful return-to-work intervention: early assessment and treatment; identification of modified work; and motivation of the worker and employer for a successful outcome (Bates, 1999).

These case studies make mention of different approaches to job accommodations. It is also important to note that more than one of these accommodations could be implemented at the same time (Bates, 1999; Campolieti, 2005). Following are a few types of accommodations mentioned in the literature:

(1) flexible work schedules (Bates, 1999; Unger & Kregel, 2003; Campolieti, 2005);
(2) reduced hours (Bates, 1999; Campolieti, 2005);
(3) task reduction (Bates, 1999 Isernhagen, 2000b; Unger & Kregel, 2003);
(4) modified equipment (Bates, 1999; Campolieti, 2005);
(5) special training (Unger & Kregel, 2003; Campolieti, 2005);
(6) modified workstations or work areas (Unger & Kregel, 2003; Campolieti, 2005); and
(7) light duties (Bates, 1999; Isernhagen, 2000b; Campolieti, 2005).

It is, however, also necessary to take note of some very important criteria for returning to work after injury. These need to be carefully reviewed and evaluated by the selected members of the disability team. According to Lyth (2001), such criteria would include the following:

(1) status of functionality in relation to the physical (or cognitive) demands of the job;
(2) possible need for job modifications and accommodations;
(3) need for adaptive equipment or assistive technology;
(4) need for provision of body mechanic training or intervention; and
(5) possible need for part-time or graduated return to work for a limited period.

2.10. Job accommodation – why implement job accommodation?

Returning to work after injury or illness is important for both the worker and the employer (Isernhagen, 2006). Lost work days, also referred to as "man days", are a constant and major concern for any company (Isernhagen, 2000a; Schonstein & Kenny, 2001). This could be brought about by a number of reasons, ranging from sick leave abuse to lack of required physical ability, to temporary-, or permanent physical impairment and disability (Schonstein & Kenny, 2001; Williams & Westmorland, 2002; Westmorland & Buys, 2004). According to Helm *et al.* (1999), workers who are injured on the job are often labelled as permanently restricted by their physicians and are then deemed permanently disabled by their employers. They also state that the cost of work-related injuries for employers and society has grown enormously in recent years and needs to be contained in order for employees to have a profitable business. Lost work days, directly related to lost productivity, usually also involve other financial losses to a company, especially where workplace injuries and illnesses are concerned. Such losses mostly include disability insurance premiums, worker's compensation premiums and worker replacement costs (Sevier *et al.*, 2000; Williams & Westmorland, 2002). Estimates suggest that annual disability costs alone could range from eight percent to fifteen percent of a company's payroll (Williams and Westmorland, 2002). Helm *et al.* (1999) reports that worker's compensation costs per claim increased from an average of $6138 in 1980 to almost $24000 in 1991 in the United States.

Throughout the world, including South Africa, various approaches have been identified and implemented in an attempt to ensure that employees in physically-demanding positions are properly managed from a physical work capacity point of view (Carmean, 1998; Helm *et al.*, 1999; Isernhagen, 2001; Schonstein & Kenny, 2001; Tuckwell *et al.*, 2002). One such approach is job- or workplace accommodation which will allow qualified individuals to perform essential job functions despite their physical limitations or disabilities (Schartz *et al.*, 2006). Job accommodation could be seen as a primary job retention intervention and have been shown to be effective in extending working life, including among older workers (Allaire *et al.*, 2003). Schartz *et al.* (2006) further states that the concept of reasonable workplace accommodation is central to non-discrimination and the Americans with Disabilities Act actually prohibits employers from discriminating against qualified individuals with disabilities in hiring, retention, promotion or termination, unless the accommodations would impose undue hardship for the business. This in turn is also in line with the Labour Relations Act No. 66 of 1995 and the Employment Equity Act No. 55 of 1998 in South Africa, both of which define unfair labour practice to include discrimination on the grounds of disability, but with the clear statement that unfair discrimination excludes discrimination based on the inherent requirement of a job (Labour Relations Act 66, 1995; Botha *et al.*, 1998; Employment Equity Act 55, 1998). This should allay the fears of some critics. These critics argue that reasonable accommodation creates an employment privilege or subsidy for individuals with disabilities. This presumes that, all else being equal, the net costs of accommodations exceed the benefits to employers and individuals with disabilities (Schartz *et al.*, 2006).

Cost of job accommodation is, as could be expected, one of the main considerations as far as implementation is concerned (Helm *et al.*, 1999; Unger & Kregel, 2003; Shartz *et al.*, 2006). Before looking at actual costs, it is important to have a holistic understanding of costs and benefits to an employer. Schartz *et al.* (2006) gives the following descriptions for direct cost, indirect cost, direct benefits and indirect benefits:

Direct cost is the out-of-pocket expenses attributable to providing the accommodation, and it includes the direct cost that is more than an employer would have paid for an employee in the same position, but without a disability.

Indirect cost could be defined as costs that are not directly related to providing the accommodation, such as lost time because of training, supervisors' time, or loss of production and it includes the indirect cost that is more than an employer would have paid for an employee in the same position, but without a disability.

Direct benefits are the estimated direct benefits to the employer from providing accommodation, such as allowing the company to hire, retain or promote a qualified employee, eliminating the cost of training a new employee, savings on workers' compensation and other insurance costs, improved employee productivity and attendance, as well as increased diversity.

Indirect benefits are the estimated indirect benefits to the employer from providing accommodations such as increased overall company productivity, attendance, morale, profitability and workplace safety, as well as an increased customer base and improved interactions with co-workers or customers.

For many, the cost of making accommodations has proven to be extremely reasonable. It is estimated that about 52% of accommodations made by employers in the United States of America cost less than $500 to implement (Unger & Kregel, 2003). Halpern (2003) more or less agrees by stating that between 1992 and 1999, 51% of the accommodations in his survey cost between $1 and $500, with only 4% costing more than $5000. According to Schartz *et al.* (2006), studies on accommodation costs have suggested that direct costs are low and benefits are substantial. In a study of more than 500 accommodations from 1978 to 1997, Blanck (1997) reported that the majority (72%) had no direct costs. About one fifth (17%) cost less than $100, 10% cost less than $500 and only 1% cost more than $500. From 1993 to 1997, the average direct cost of an accommodation was $45. In contrast, the average administrative costs for replacing an employee were between $1800 and $2400 (Blanck, 1997). Schartz *et al.* (2006) also reports on data derived from a sub-sample of interviews with employers conducted between January 2004 and June 2005. Of the 329 accommodation solutions implemented by these employers, 259 respondents were able to provide actual or estimated direct cost data. In 49.4% of the cases, employers reported that there was zero direct cost associated with the accommodation. Of the remaining 50.6% that had a cost, the median first calendar year's direct cost was $600. Of the 152 employers providing estimates of indirect costs associated with the accommodation, 84.9% reported that there were no indirect costs associated with the accommodations. Interestingly, the more effective the implemented accommodation, the lower the employer rated the individual's work limitations when accommodated.

Dowler *et al.* (1996) reported on a 1996 study, which included 372 job accommodation cases. The median cost of workplace accommodations were $200. Almost one fifth (18%) involved no costs and slightly less than half (48%) cost between $1 and $500. Data from the Job Accommodation Network (JAN) in the United States indicates that from 1992 to 1999, employers who sought their assistance reported a median cost of $250 for accommodations, compared to a median benefit of $10,000 for providing job accommodations (Schartz *et al.*, 2006).

Schartz *et al.* (2006) also claims that 95 of the employers involved in their study provided a monetary estimate of direct benefits, which ranged from $0 to $116,000, with a median of $1000. Of the 62 respondents which reported direct benefits greater than zero, the median direct benefit was $5500. Furthermore, the vast majority of employers reported the following direct benefits:
(1) retaining of a qualified or valued employee (87.1% of the employers);
(2) hiring of a qualified or valued employee (16.7% of the employers);
(3) promotion of a qualified or valued employee (11.5% of the employers);
(4) increasing the productivity of the affected employee (73.8% of the employers);
(5) eliminating the cost of training a new employee (55,4% of the employers);
(6) increasing the attendance of the accommodated employee (50.5% of the employers);
(7) saving on worker's compensation and other insurance (41.8% of the employers); and
(8) increasing diversity of the company (43.8% of the employers).

When looking at the indirect benefits reported by the participants in the study by Schartz *et al.* (2006), 77 respondents (57.1%) reported no indirect monetary benefits associated with providing job accommodations. Of the 33 respondents with indirect benefits greater than zero, the median indirect benefit was $1000. Respondents also reported the following indirect benefits:

(1) improved interactions with co-workers (69.3% of the employers);
(2) increased overall company morale (60.7% of the employers);
(3) increased overall company productivity (57% of the employers);
(4) improved interactions with customers (42% of the employers);
(5) increased workplace safety (42.3% of the employers);
(6) increased overall company attendance (36% of the employers);
(7) increased profitability (29.4% of the employers);
(8) increased customer base (15.5% of the employers); and
(9) other indirect benefits (9% of the employers).

Existing empirical evidence suggests that workplace accommodations typically are effective and inexpensive, but the primary economic benefits to an employer of providing job accommodations may be in retaining employees and avoiding the costs of job searches, hiring and training replacement employees (Schartz *et al.*, 2006).

Job accommodation literature reports on several benefits and advantages of job accommodation implementation. Well-documented benefits of such an intervention include:

(a) prolonging the employment of disabled or permanently-impaired employees (Allaire et al., 2003; Campolieti, 2005; Nilsson *et al.*, 2007);
(b) facilitating the return to work of impaired employees (Schonstein & Kenny, 2001; Campolieti, 2005);
(c) delaying the exit of workers to the disability rolls and prolonging their employment spells (Allaire *et al.*, 2003; Campolieti, 2005);
(d) assisting the company in retaining productive and qualified employees (Unger & Kregel, 2003); and

(e) assisting non-disabled coworkers to better perform the duties of their jobs (Unger & Kregel, 2003.

Williams and Westmorland (2002) evaluated the effectiveness of modified work programmes with respect to return to work on the basis of 13 high quality studies. The findings showed that:

(a) modified work programmes facilitate return to work;
(b) rate of return to work for injured workers who are offered modified work is double;
(c) modified return-to-work programmes reduce the number of lost days in half; and
(d) modified work programmes are cost effective.

Schonstein and Kenny (2001) furthermore reports on a systematic review on modified work. The main finding of this review is that injured workers who are offered modified work have twice the rate of "return to work" as those who are not. Similarly, modified work programmes cut the number of lost workdays in half, making these interventions cost effective. They also compare these findings to a synthesis of intervention studies for the management of acute lower back pain, concluding that there is substantial evidence indicating that employers who promptly offer appropriately modified duties can reduce time lost per episode of back pain by at least 30%, with frequent spin-off effects on the decreased incidence of new back pain claims.

According to Isernhagen (2000a), most employers share similar goals when they consider their work-injury prevention and disability management needs. It is interesting to note that most of these goals could be achieved by applying proper task-specific job accommodation in physically-demanding positions. These goals include, but are not limited, to the following:

(a) to decrease the cost of disability (short term and long term) for work and non-work-related injuries and illnesses;
(b) to decrease the number of lost work days due to injuries and illnesses;
(c) to reduce the number of restricted days due to injuries and illnesses;

(d) to decrease recordable injuries;
(e) to reduce the number of injuries that occur to new employees;
(f) to decrease the number of new employees who resign during the first year of employment;
(g) to reduce the number of injuries associated with an ageing work force;
(h) to reduce the risk of discrimination lawsuits associated with hiring practices;
(i) to increase productivity; and
(j) to increase employee morale.

Helm *et al.* (1999) reports on an example of company savings by implementing an early return-to-work programme for 1800 employees. In this example, the company's cost per claim was $3824 per claim in 1990. With inflation, the estimated cost per claim for 1992 would have been $4970. However, the company's cost per claim was reduced to $1525 through the implementation of a work-injury management programme. This company had 300 claims per year, the savings ($3445 X 300) was over $1 million for 1992. Halpern (2003) claims that a survey shows that companies reported an average return of $34.58 in benefits for every dollar invested in making an accommodation.

Now that all the benefits, costs, and other "whys" of implementing job accommodation have been discussed, it is important to note that this thesis places all the focus on "task specific" job accommodation. In the literature, very little mention is made of this. Schonstein and Kenny (2001), however, summarised information provided by medical doctors regarding fitness to return to work for workers needing a gradual return to work. Assessing whether job accommodations or modifications are necessary is a critical function of an occupational health doctor (Serra *et al.*, 2007). Schonstein and Kenny (2001) indicated that most doctors felt able to specify whether workers were fit for suitable duties or not. However, most were not prepared to specify the number of hours or days a worker would be able to work per day or week. This indicates that doctors may have insufficient information for this kind of recommendation. They state that the more objective information the doctor has, the more able he / she will be to recommend a gradual return to work that specifies hours of duties. Doctors are also reluctant to specify in kilograms the restrictions imposed on most weighted work tasks. The exception seems to be lifting, where the limits on weights imposed vary from 2 kg to 20 kg, with most recommended weights being around 5 kg to 10 kg. They do, however, recommend broad restrictions, such as “work in clean environment”, “avoid repetitive work with right arm”, “no heavy lifting”, or “no prolonged or repetitive bending, stooping or pushing”. Bates (1999) provides case studies which support these findings. Schonstein and Kenny (2001) states that doctors lack sufficient knowledge of the workers’ workplace and work demands, as well as a standardised method of assessing physical work capacity. From the employer’s point of view, these recommendations are vitally important, and its absence could lead to confusion and ultimately delays in the provision of suitable duties. Unger and Kregel (2003) further states that supervisors most often cite their human resource personnel, disability coordinator, or other supervisors as sources of assistance during job accommodation. Occupational health professionals clearly have a huge part to play in providing these role players with objective, scientific and task-specific information to assist them in making informed decisions.

This thesis attempted to develop an objective, task-specific job accommodation tool by making a direct link between actual physical ability and the actual tasks of a physically-demanding job. The final result will hopefully fill the gaps mentioned above. The need for such a tool is also clearly stated by Helm *et al.* (1999), who mentions a suggestion by a previous researcher. This researcher suggested the use of an ability profile to identify worker abilities. This is a detailed checklist that is filled out by the physician, indicating the level of ability with regards to work demands. They go further in saying that the occupational therapist implementing the return to work model may need to develop a similar tool to help identify abilities and restrictions that are specific to the work environment. McKenney (2000) also proposes such an approach, which involves functional ability evaluations, administered by a trained physical therapist or an occupational therapist. However, this proposal does not make mention of the applicable test battery being linked with specific tasks found within the relevant physically-demanding job.