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CHAPTER 1: MINIMUM PHYSICAL REQUIREMENTS FOR PHYSICAL WORKERS - THE PROBLEM:

1.1. Introduction:

Biokinetics within the corporate world is a relatively new phenomenon in South Africa and until recently the only involvement seemed to happen at managerial level. The focus is however starting to shift to the so called "blue-collar worker" or physical worker and new methods are constantly being developed to assist these employees (and ultimately the company they work for) from a biokinetics point of view.

This study focussed on a big South African electricity supply company (more specifically the northern region of this company) where biokineticists have been permanently employed to assist in taking care of the work force through biokinetic interventions. In this specific company a substantial percentage of the work force are classified as blue-collar workers, and therefore, these employees need to be physically capable of performing certain outputs in order for the company to deliver a service to its customers. To achieve this goal, the three focus areas of corporate biokinetics (physical assessments, physical rehabilitation and preventative biokinetics - according to biokinetics directives currently in use within the relevant South African electricity supply company) are constantly being adjusted to ensure that it fits in with the unique working circumstances and physical strains that these workers have to endure on a daily basis .

For the past six years, the biokineticists who work with these people have constantly been challenged to come up with new methods and ideas in an attempt to provide an effective service. Consequently corporate biokinetics became more and more mobile and the corporate biokineticist started working more and more proactively.

One of the main realisations (by the company concerned as well as by companies with a physical work force world wide) was that any employee who is not physically strong enough or cardiovascularly fit enough to perform the daily outputs required of him or her will become an increasing risk to the company in terms of lower individual productivity and eventually lower productivity of the company in general (Campion, 1983). The probability also exists that these employees run a higher risk of injuring themselves and other work colleagues when compared to those who are physically able to perform the outputs properly (Bernauer & Bonanno, 1975; Campion, 1983; Hessel & Zeiss, 1988). According to Malan (1992) and Malan and Kroon (1992) it is estimated that 115,000 back injuries occur in South Africa every year (this results in financial losses of R800 – R1000 million per year) and approximately 23% of these injuries can, at least partially, be prevented through the application of a scientifically based physical selection programme.

Jackson (1994) reports a strong relationship between the incidence of back injuries among fire-fighters and level of physical fitness. According to Jackson an earlier study by Cady *et al.* (1979) showed that the reported back injury rates of fire-fighters looks as follows when deviding them into three groups according to level of physical fitness: least fit, 7.1%; middle fit, 3.2%; and most fit, 0.8%. The back injuries of physically fit fire-fighters were also less costly than the injuries of those who were less fit. Jackson (1994) also refers to a study where very similar results were found with electrical lineworkers. This study reported a significant correlation between worker scores on strength and endurance tests and the incidence of lost workdays due to on-the-job injuries. All this information indicates that biokinetics has a role to play in the world of physical labour.

In biokinetics reports compiled in 2001 & 2002, the financial implications of physical injuries on the South African electricity supply company under scrutiny (from here on referred to as "SA ELEC") and the importance of early intervention as part of an injury prevention programme was indicated in no uncertain terms (Lubbe, 2001; Lubbe, 2002). From 1995 – 1999, 721 employees within the company applied for ill health retirement. Of the 721 applications, 436 were approved (57% of these conditions being of a musculo-skeletal nature), leading to a cost to the company of R130 925 581.08 for this 5 year period (Lubbe, 2001). When one takes into consideration that this leads to other losses (such as money loss for the hiring of temporary staff, money and time loss for the recruitment and training of new employees and productivity loss due to loss of experience and training periods for new employees, to name but a few), the eventual amount lost by the company is astronomical.

In 2001 and 2002, biokinetics projects within SA ELEC showed the financial benefits of early identification of potential "ill health retirement employees" in order to intervene before potentially incapacitating musculo-skeletal injuries do occur (Lubbe, 2001; Lubbe, 2002). The projects made use of a programme which consisted of the physical testing of blue collar employees, comparing the test results with the "minimum physical requirements" (MPR) for each individual`s job, identifying candidates based on these MPR as well as other relevant information and making use of intensive physical conditioning / -rehabilitation cycles (six weeks each) to improve each person`s physical ability. Employees from across the country took part in these cycles and it was estimated that the company saved R655 860.00 during 2001 and R2 354 498.41 during 2002 because of the early identification and subsequent conditioning / rehabilitation of these employees. This can also be expressed as return on investment: for every R1.00 invested in the programme by the company in 2001, R2.35 was saved and for every R1.00 invested in the programme by the company in 2002, R6.77 was saved. These savings are made through sick leave reduction, employee turn over reduction, ill health reduction and productivity improvement. There was an average physical ability improvement of 12% in 2001 and 11.7% in 2002, average attitude improved by 15.4% in 2001 and 33.1% in 2002, average lifestyle habits improved by 21.1% in 2001 and 29.2% in 2002, average cardiac risk was reduced by 3.1% in 2001 and 5.9% in 2002 and there was an average productivity improvement of 13.3% in 2001 and 22.5% in 2002 (Lubbe, 2001; Lubbe, 2002).

These figures quickly brings one to the realisation that such interventions have a vital role to play in the sustainability of a company. The interventions and the results of intervention will however have no ground to stand on if the tools for identification and measurement of improvement are not in place. This is why the development of MPR are vital to companies with a physical labour force and why there should constantly be striven to improve these tools of measurement.

The idea to make use of MPR originated in the United States of America. This was done in order to establish an objective tool for measuring the blue-collar worker`s physical capacity to do his / her job effectively. In the USA this approach have been in use for many years as part of their selection process and to ensure that the employee is placed in the job most suited to his / her physical capabilities (Chaffin *et al.*, 1978; Fleishman, 1979; Davis & Dotson, 1987; Malan, 1992). In South Africa, however, this is a very young field that has only been looked at seriously in very recent years. The possibilities therefore are endless, especially for the biokinetics profession (specialists in the field of physical testing).

Within SA ELEC, biokinetics work has been committed to the development of MPR for each physical job in the company for the past three years. This approach is essential in working proactively with the blue-collar worker. These MPR are already being used for the purpose of early identification of high risk cases in order to ensure that the intensive rehabilitation / conditioning programmes which are in place involve the correct employees. The aim of these programmes are to improve the physical capacity of the identified employee in order for this person to meet the MPR for his / her particular job (or to at least improve the individual from a high risk to a moderate risk). The MPR are also used after the completion of rehabilitation / conditioning programmes and at set intervals during these intensive programmes. The purpose of this is to monitor progress and to determine whether the individual has made sufficient progress to return to his / her normal duties without being a risk for the company. It seems obvious that individual- and over all productivity can be improved considerably by making use of MPR at every possible opportunity, but due to certain restrictions within the labour laws ("Labour Relations Act 66 of 1995"), this tool is not yet being used for preplacement and replacement purposes within South Africa, as explained by Botha *et al.* (1998). The obvious advantages of preplacement and replacement testing suggests, however, that South Africa will have no other choice but to jump on the international band wagon sooner rather than later.

The MPR currently being used in SA ELEC were devised by the companies` biokineticists through the following process: identification of the critical physical tasks involved in each physical job, analyses of each of the identified tasks, identification of the critical physical factors involved in each task and then testing these critical factors in each of the applicable employees. For example, after analysing a task which involves the lifting of heavy implements from the ground, certain critical factors such as leg strength, back strength, arm strength, grip strength and abdominal endurance may be identified as the critical factors in performing this task. These critical attributes / factors are then tested, MPR are devised, each individual is compared with the MPR and the result is that certain problem areas can be identified (in each individual and in the group as a whole).

These MPR form the back bone of physical tests on physical workers in the company and therefore the intension of this study was not to challenge or replace the work that has already been done or the MPR that were already in place. The goal was rather to add to this tool and to establish a better, more complete and more significant tool. This thought led to the realisation that the one big shortcoming of the factor approach is that it doesn`t measure strength in a work specific manner and therefore a critical gap in the assessment of physical work capacity is not being attended to. The roots of this study was born with the realisation that a battery of work specific tests, which measures the critical physical tasks in a work specific manner, can be of great value in addition to the already existing factor tests. The result would be one very powerful tool, which consists of MPR for the factor tests, and MPR for the work specific tests (the best of both worlds).

1.2. Problem setting:

What are the minimum physical requirements (MPR) for blue-collar workers within a specific department of an electricity supply companies` northern region when making use of work specific physical tests?

1.3. Hypothesis:

It is possible to calculate the minimum physical requirements (MPR) for blue-collar workers within the northern region of an electricity supply company by making use of objective, work specific physical tests.

1.4. Purpose and aim of the study:

There are many obvious purposes for establishing a measuring tool such as this (most of which having served as the documented reasons for conducting this study because of their direct relation to the success of the company), which includes the early identification of high risk cases in terms of productivity and possible injury, preplacement, replacement, pre- and post conditioning assessment, etc. It is however also vitally important that the field of job-related physical assessments is explored and researched to the extent where South Africa is established as one of the leading countries in this field. This study should therefore be seen as another small step towards this goal. With so many companies where physical labour forms the backbone of the company, it makes sense that this is not a field we can afford to ignore. Not only does the longevity of these companies depend on a physically able work force, but also the very economy of our country is directly (and greatly) affected by the success of many of these companies with large physical work forces.

Biokineticists are perfectly equipped to fill this gap and this study should not only be seen as a typical study with a typical result or product, but as another step in a direction that has been neglected by the health professionals of this country:
"The physical capacity of the blue collar worker".

Therefore, the aim of this study was to identify and design a battery of work specific tests for the blue collar workers within one of the departments in SA ELEC`s northern region, and to establish work specific MPR for them. The idea was to establish one powerful and complete measuring tool, which consists of MPR for the factor tests (already in use in SA ELEC), as well as MPR for the work specific tests (the result of this study).

CHAPTER 2: LITERATURE REVIEW:

2.1. The history of job-related physical assessment (with special focus on the two traditional methods):

The testing of physical performance abilities undoubtedly had its origin in such contests as the early Olympics. Combat-related tasks such as the javelin throw, running and wrestling were directly related to necessary soldierly skills (Davis & Dotson, 1987). More recently, in 1912, Brezin and Kolmer (1912) appeared to have conducted the first empirical analysis of modern military tasks and in a classic 1923 job analysis of the Royal Army, undertaken by Cathcart *et al.* (1923), it was noted that "the heavier loads were a distinct menace to the maintenance of normal cardiac activity". Existing records such as these certainly indicate that the idea of assessing physical ability is not a new one, albeit that the use of such methods is certainly no longer limited to the military.

Davis and Dotson (1987) states that entry level testing for physical abilities in jobs with physical performance requirements has taken some very interesting turns. In a number of municipalities, no testing was required for decades. With the advent of women entering what had been traditionally male dominated occupations, came the development of entry level tests (Washburn & Safrit, 1982; Davis & Dotson, 1987). Furthermore, new world wide laws concerning the employment of the disabled showed a number of shortcomings in the procedures being followed when selecting employees. Most of these procedures were misleading and irrelevant as they were based on assessments which showed little similarities with actual work requirements (Meier, 1998). Out of these and related considerations has arisen a new approach to the evaluation of potential employees, based on the concept of matching the functional capacities of the individual to the physical demands of the job (Fraser, 1992).

The unfortunate caveat to all this testing was that proposed tests often failed to demonstrate any relationship to performance on the job, and if a test was passed upon entry, there never again came any requirements to prove possession of adequate levels of physical ability and fitness. Obvious shortcomings like these lead to the "Uniform

Guidelines on Employee Selection Procedures" being published in 1978. This document, commonly referred to as "The Guidelines", spelled out the requirements for the development of job-related tests and a lot of emphasis was placed on job-related reliability and validity (Davis & Dotson, 1987).

Employers have been using some or other method of selecting an employee among potential job applicants for many years (Brownlie *et al.*, 1985; Jackson, 1994; Biddle & Sill, 1999). In the United States of America, the rapid rise in the use of standardised tests for job placement can be traced to the country`s need for rapid mobilisation and utilisation of human resources during the first and second World Wars. The goal was to match military personnel to jobs on the basis of test performance. The development of preemployment tests grew out of the discipline of psychology and the early success in measuring differences among people. The common theme of this work was that persons differ from each other in reasonable, stable ways, on some number of attributes and that patterns of individual attributes are more or less suited to particular patterns of job requirements (Jackson, 1994).

Much of the early preemployment testing in the U.S.A. focussed on cognitive abilities, but with the rapid rise in women seeking physical jobs, the need for preemployment physical ability tests increased (Washburn & Safrit, 1982). In 1982, Campion (Campion, 1983) suggested that there was a need for better methods of selecting personnel for physically demanding jobs for at least three reasons:

(1) equal employment opportunity legislation resulted in greater numbers of females and handicapped individuals seeking employment in occupations requiring high levels of physical ability;
(2) there was evidence suggesting that physically unfit workers had higher incidences of lower back injuries; and
(3) preemployment medical evaluations used alone are inadequate for personnel selection regarding a physically demanding job.

Medical evaluations have been known to be the method of assessment used by large companies for the placement of potential employees regarding jobs with physical requirements (Fraser, 1992; Meier, 1998). According to Hogin and Bernacki (1981), most of these assessments and evaluations focus on the physical and medical aspects of good health and they do not show any relevance when looking at the actual tasks to be performed. This often leads to an employee being appointed according to the medical results, even though his/her physical capacity is not sufficient for the successful execution of the physical tasks required by the job (Campion, 1983; Fraser, 1992; Hayes *et al.*, 1995). It is clear that this method of selection will pose major problems for the companies that choose to use it and that a process which consists of task orientated physical ability analysis and –selection is required (Malan, 1992). Campion (1983) names the following advantages of selecting employees whom are physically strong enough to perform the required tasks optimally:

(a) improved productivity;

(b) reduction in injury related incidents;

(c) reduction in labour hours lost; and

(d) reduction in complaints due to work fatigue.

Another reason why there`s been so much interest and research on preemployment test methodology for physically demanding jobs in the U.S.A. during the last few decades and today is because of federal civil rights legislation and court decisions on employment practices in that country (Biddle & Sill, 1999). In 1964 the U.S. Congress passed the Civil Rights Act. Among other things, this act prohibits employment discrimination based on race, colour, religion, sex or national origin. In 1966, their Equal Employment Opportunity Commission (EEOC) published the first set of guidelines on employment testing, which were revised in 1970. This led, in 1978, to the publication of the Uniform Guidelines on Employee Selection Procedures. The EEOC, Civil Service Commission, and Departments of Labour and Justice jointly agreed upon these federal standards and rules. Furthermore, the American with Disabilities Act extended legal protection from employment discrimination to handicapped Americans (Jackson, 1994).

Although some form of selection method has always been used to select employees for a job, the legal controversy surrounding employment testing in the U.S.A. is only about 30 years old. The initial and majority of legal cases concerning preemployment testing involved racial and ethnic discrimination by paper and pencil cognitive tests (Arvey & Faley, 1988), but with the increasing interest of women seeking jobs traditionally held by men, 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 preemployment test is valid (Arvey & Faley, 1988). In the 1960s, height and weight standards were a condition of employment for many public safety jobs, and these standards will clearly have 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 ruling turned out to be the first step of many in terms of job related physical testing. Of the ten documented cases involving physical tests, all involved police and fire-fighter preemployment tests, and eight were won by the defendants, who were job applicants (Jackson, 1994). The common test development approach that emerged from these cases was the use of general physical ability and fitness tests such as sit-ups, push-ups, pull-ups, squat thrusts, and various general strength and endurance tests. Arvey and Faley (1988) maintains that these tests are less likely to be legally supported because they do not represent “samples” of actual work behaviour. Biddle and Sill (1999) also points out that the American courts have through the years consistently required a validity coefficient of .30 or greater in physical ability test cases that have appeared before the courts. All these bits and pieces added to the development of job related physical testing and physical preemployment testing to the point where it can be seen as part of a fair selection and identification process.

Another major force motivating companies to initiate preemployment physical tests is the need to reduce work-related injuries and, in the process, contain workers` compensation costs. Many occupations have a high incidence of musculoskeletal injuries, of which a very high proportion affect the lower back (Chaffin, 1974; Yu *et al.*, 1984; Van Niftrik, 1996; Craig *et al.*, 1998; Waddell and Burton, 2001). In a comprehensive survey of insurance claims for back injuries, Snook *et al.* (1978) reported that the major occupational acts associated with lower back injury were lifting, 49%; twisting and turning, 18%; bending, 12%; and pulling, 9%. Craig *et al.* (1998) concluded from 200 occupational health and safety reports, that lifting and lowering are the main activities that`s associated with back injuries.

Three ergonomic approaches are most commonly used to reduce the number of industrial back injuries:
(a) redesign physically demanding jobs;
(b) use preemployment tests for workers of physically demanding jobs; and
(c) education and training (Snook, 1988).

Of the three methods mentioned, this study puts the focus on physical testing (in this context referred to as preemployment testing) and therefore points "B" and "C" will not be discussed in further detail.

Preemployment testing is the preferred ergonomic approach for those physically demanding jobs that cannot be redesigned (Snook, 1988). The goal is to match the worker`s physiological capabilities with the physical demands of the job. The strategy to control injury is one of selecting only those individuals with the physical capacity and functional capabilities to perform a given job without excessive risk (Ayoub, 1982; Snook, 1988; Lukes & Bratcher, 1990; Toeppen-Sprigg, 2000).

Strength testing is and has always been the most effective job placement technique for materials-handling tasks (Snook, 1988) and one of the most effective approaches in limiting work-related injuries (Snook, 1988; Malan, 1992). The hypothesis behind this approach is that there is a relationship between the probability of injury and the percentage of strength capacity used by the worker in job performance (Snook, 1988). For example, if a job required lifting a 100 pound object using the back, the individual with a lifting capacity of 100 pounds would be more prone to injury than one with a lifting capacity of 200 pounds (Ayoub, 1982).

The types of tests most commonly used (traditionally) in physical ability preemployment tests can be put into two general categories. The type of tests used for content validation studies are job-sample tests or tests that simulate important work tasks identified with the job analysis. The second general type of tests are those that comprise motor ability and physical fitness batteries. As previously mentioned, the use of motor ability and physical fitness tests are likely to increase the chance that a preemployment test will be challenged in the courts. A work-sample test, on the other hand, represents observable job behaviours (Jackson, 1994; Hough *et al.*, 2001).

2.1.1. Work-sample tests

The advantage of work sample tests is that they simulate the actual working conditions and are more likely to have content validity (Hough *et al.*, 2001). Lifting and carrying a heavy object (like a toolbox) a specified distance is an example of a materials-handling work-sample test. While work-sample tests have the advantage of appearing to be valid in terms of content, Ayoub (1982) maintains that they have at least two limitations. The first is safety. Applicants seeking employment are likely to be highly motivated to pass the work-sample. A highly motivated applicant who lacks the physical capacity to perform the task is likely to increase the risk of injury. Some tasks are also simply too dangerous for an untrained applicant to perform as part of a work-sample test (climbing tasks, for example). A second limitation of job-simulation tests is that they do not give any information about the applicant`s maximum work capacity. A work-sample test is often scored by "pass" or "fail" (e.g., lifting and carrying a 95 pound jackhammer a specified distance). Some applicants may complete the test very easily, while others may just pass and be working near their maximum physical capacity (Ayoub, 1982; Jackson, 1994). If it can be assumed that there is a linear relationship between job performance and the preemployment test performance, applicants with the highest test scores can be expected to be the more productive workers. Testing for maximum capacity also provides the opportunity to define a level of reserve that may reduce the risk of musculoskeletal injury (Jackson, 1994). It is clear that work-sample tests do have a few crucial limitations when it comes to preemployment- and other related tests. Now let`s take a look at the pros and cons of the other traditional testing method.

2.1.2. Motor ability and fitness test items

Numerous investigators (Baumgartner & Zuidema, 1972; Bernauer & Bonanno, 1975; Fleishman, 1979; Malan, 1992) have conducted factor analysis studies that identified the constructs of human physical performance. Physical ability constructs (such as static strength, dynamic strength, trunk strength and flexibility) are identified through a validation study, specific tests are used to measure these constructs and then cut scores (the test score that an applicant must obtain in order to be considered for the job) are set for each test. The biggest concern and most crucial limitation to be conquered when making use of this type of preemployment testing is the question of validity (Jackson, 1994; Hough *et al.*, 2001). For example, the tests used should be representative of the vital and challenging physical activities to be performed in the job and the cut scores should be reasonable and consistent with normal expectations of acceptable proficiency within the work force. Hough *et al.* (2001) states that tests measuring physical ability constructs are often defended on the basis of criterion-related validity, as apposed to content validity.

One big advantage of this approach is the objective measurement of an applicant`s maximum work capacity. This allows valuable information when considering employment, as apposed to a "pass" or a "fail" score. A good case could also be made for improved safety when performing such tests. Firstly, because the candidate does not know what the cut score is and therefore is more likely to perform to his/her maximum without over exertion, and secondly, because these tests are usually performed in a more controlled environment and the candidates are forced to perform the tests in a specific, safe manner (Jackson, 1994).

2.2. Job-related physical assessment in South Africa:

In 1992, Professor D.D.J. Malan (Malan, 1992) wrote an article called "Fisieke evaluering as metode van seleksie voor indiensneming en arbeidsplasing met die oog op verbeterde produktiwiteit en verlaagde beseringsrisiko". This article focussed on job related physical assessments (Physical Ability Analysis) and more specifically on the unique role this could play in South Africa. He is seen as an expert on this topic and a trendsetter in South Africa as far as the assessment of physical work capacity is concerned. Here is what he, and others, had to say on the role of Physical Ability Analysis in South Africa:

One of the characteristics of South Africa, as a still developing industrial country, is the unavoidable utilisation of manual labour. This country is also caught up in the very interesting scenario where it is part of a first world industrial technology race, which is largely served by a third world population group. For many years the mining industry has been reliant on manual labour with as many as four-hundred-thousand contracted workers working in South African mines during the mid twentieth century. In many cases there was an annual worker turnover of up to 100%. This contributed greatly to establishing the appointment/hiring of man power as a critical factor in the mining industry and eventually there was no other alternative but to start making use of self developed selection methods (Malan, 1992).

Physical examination in the South African mining industry dates back to 1916, when miners were examined at 6-month intervals. This included tests to assess the worker`s ability to continue their jobs without endangering themselves or others (Hessel & Zeiss, 1988). The idea of measuring physical work capacity is therefore not a new one in the industrial world of South Africa, but constant development and implementation of new ideas is necessary in order to improve the methods and the standard of physical work capacity measurement in order to ensure progress and conformance with the constant changes in the work environment (Malan, 1992; Malan & Kroon, 1992).

According to research done in South Africa, numerous companies consider their manpower/human resources to be their most important asset. This implies that the company strives toward employing only the best workers to ensure that they contribute positively to the productivity of the company. The success or failure of each and every company therefore greatly depends on the quality of worker that is being employed (Holder, 1992; Malan, 1992).

A company doesn`t only benefit from employing healthy employees, but the worker also has to possess the physical capacity to do his/her job and the required tasks effectively. One of the ways to ensure this is through preemployment assessment which will ensure that the right employee is selected for the job. Another possibility is to physically assess all current employees and to use these tests to ensure more effective utilisation of the work force, either through re-placement or physical conditioning/rehabilitation (fitting the man to the job). This will also be a more acceptable approach to improved productivity than reducing the number of employees (Campion, 1983, Malan, 1992; Malan & Kroon, 1992).

In South Africa, the selection of workers (blue-collar workers) based on their physical ability is a fairly unexplored and neglected component of the preemployment process. This is rather surprising since work effectiveness in many jobs is equally based on both the physical- and the (often-evaluated) psychosociological components of a person. In South Africa, the employment of physical workers is mostly based on the immediate need of the company and employment is often based on the physical appearance of the candidate (face value) (Malan, 1992). Among the South African companies that employ large numbers of manual/physical workers (including SA ELEC), it is true that medical evaluations often play a substantial role in the selection process (Hessel & Zeiss, 1988; Malan, 1992; Botha *et al.*, 2000). These evaluations however place most of the focus on the clinical- and the health components of the worker and don`t always pay attention to the physical abilities of the employee before placing him/her in a specific job (Malan, 1992).

Other aspects that are commonly looked at in stead of physical ability are:

- BMI (body mass index **or** height- / weight ratio) – this method is often preferred when a group of workers have to be selected from a large number of candidates;
- step-up test – the mining industry have been known to employ this method as part of their selection process;
- work history of the applicant – absenteeism and accidents, for example; and
- skill level of the applicant – courses attended, for example (Malan, 1992).

It is clear to see that none of the above mentioned methods are sufficient for proper selection purposes as none of them test the different aspects of physical ability and none of them are job-related or work specific. In short, none of these tests or procedures can be used to determine the actual physical work capacity of a person.

A human being, as a productivity factor, differs greatly from other productivity factors. A few examples of this is that people are not easily manipulated, people differ greatly, people have various unique characteristics and each individual has his/her own abilities and shortcomings (Malan, 1992). In South Africa, the situation becomes even more complex and unique when one considers that the majority of the work force who make themselves available for manual labour, experience poor development of physical- and mental skills due to a variety of circumstances (Holder, 1992; Malan, 1992). It is also a well-known fact that certain race- and ethnic differences in physical abilities do exist. South Africa also differs greatly from the international community in various aspects, therefore international standards (as with psychometric tests) can not be used for assessing the physical abilities of manual labour workers in South Africa (Malan, 1992).

Everything considered, it is difficult to understand why the employment of physical workers in South Africa still takes place in an unsophisticated and random manner. There are no worker- or job-related criteria available for physically based selection. There is a definite need for criteria that is directly based on the requirements of the work tasks and norms that are set through the actual functioning of the industry. All criteria should be based on the unique characteristics of our industries and large companies (Malan, 1992).

In South Africa, as is the case all over the world, labour is becoming an increasingly expensive expenditure (Malan, 1992). South African companies have experienced an unprecedented rise in the incidence of disability among its working population between 1992 and 1994 when compensation on successful disability claims rose by an alarming 176% (Van Niftrik, 1996). This country, and its companies, simply can not afford to continue with the bad labour provision procedures that`s been in use up till now (Malan, 1992).

The advantages of having the correct procedures for selecting and managing physical workers are well known and many countries (especially the U.S.A.) have implemented it to great effect (Bernauer & Bonanno, 1975; Campion, 1983; Hessel & Zeiss, 1988; Garg & Moore, 1992; Malan & Kroon, 1992; Jackson, 1994; Carmean, 1998). South Africa has always had the need for such procedures, but until recently the development of scientifically based physical selection procedures have remained nothing but a thought (Malan, 1992). Thanks to trendsetters like Malan (1992), South Africa is now starting to wake up to the possibilities of such developments and companies like SA ELEC have started to implement these amazing tools. This study will possibly make further contributions to this field and other biokineticists will start to realise their potential in making a major contribution to the economic growth of our country.

2.3. Job analysis:

Fleishman (1979) explains that 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.

Shrey and Lacerte (1997) states that the test administrator must have a clear and precise understanding of the physical demands for each of the tasks that are crucial to the successful performance of the job. Once the crucial demands are identified, the test battery must be designed to assess the individual`s ability to perform the work tasks.

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). 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 standardizable); and they should

(e) consist of truly arduous factors that have the greatest discriminatory power.

It is clear that the focus in this section 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. A few widely preferred methods and concepts that generally apply to the analysis of jobs and their ability requirements will be described. Shrey and Lacerte (1997) identified four methods.

2.3.1. Interviews:

Interview the workers to be tested. 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; Toeppen-Sprigg, 2000);

2.3.2. Job descriptions:

Obtain a job description from the employer. Written job descriptions provide an overview of the worker requirements (Meier, 1998). Usually, these descriptions do not contain enough detail from 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; Toeppen-Sprigg, 2000);

2.3.3. Videotapes:

Obtain a videotape of the job. 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; Toeppen-Sprigg, 2000); and

2.3.4. Job-site assessments:

Perform a job-site assessment. 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 first three 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; Toeppen-Sprigg, 2000).

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).

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).

The term "skill", on the other hand, refers to the level of proficiency on a specific task or job. When we talk about proficiency in operating a front-end loader or in flying an aeroplane or in 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 (Fleishman, 1979; Magill, 1993).

The distinction between abilities and skills allows one greater precision in describing, understanding and predicting many complex human performances (Fleishman, 1979; Magill, 1993). Now let`s turn to the analysis of physical abilities.

Fleishman clearly state that there is no such thing as general physical proficiency. Such information comes from a great deal of research in which actual performances were observed on a great variety of physical proficiency tasks. As it turned out, people who were good at certain groups of tasks were not necessarily good at others. From various analysis of these statistical correlations among tasks, it was possible to specify the minimum number of physical abilities that need to be considered in evaluating the proficiency of individuals in this area (Fleishman, 1964; Fleishman, 1979; Magill, 1993).

As is well known, there are hundreds of physical proficiency tests and various kinds of labels that are applied to abilities in this area (Fleishman, 1979; Magill, 1993). For example, we often hear terms like agility, co-ordination, speed, strength, flexibility and so forth. How does one decide which labels to use and which categories to assume in analysing the abilities of people and the requirements of physically demanding jobs (Fleishman, 1979)?

2.3.5. Fleishman`s basic abilities:

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 himself. It is these nine abilities which can be used to evaluate the physical abilities required in new jobs and it is these nine abilities which provide a basis for selecting tests to measure each of the separate abilities. The abilities include four strength factors, two flexibility factors, a co-ordination factor, an equilibrium factor and a stamina factor. Here follows a detailed description of each of the nine ability factors as described by Fleishman (1979) and Magill (1993):

2.3.5.1. 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). 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).

2.3.5.2. 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).

2.3.5.3. 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).

2.3.5.4. 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). For example, broad jump and high jump tasks involve this ability, as do short runs, such as the shuttle run and 50-meter dash (Jones & Prien, 1978; Fleishman, 1979).

2.3.5.5. Extent flexibility:

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).

2.3.5.6. 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).

2.3.5.7. 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).

2.3.5.8. 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 on 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).

2.3.5.9. 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. 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).

Fleishman and Hogan (1978) have developed a technique entitled the "Physical Ability Analysis Approach" which was specifically designed to assess the extent to which a job requires the nine different abilities described previously. The technique involves the use of a manual containing nine rating scales, one for each of the different physical abilities. For each ability, there is a set of definitions which explains the ability and a chart which differentiates the ability from the other abilities with which it might become confused by an observer. Accompanying each definition is a rating scale which includes concrete examples of tasks representing different amounts of that ability. These examples represent a wide variety of tasks which would be familiar to raters using the scale, so that no special training is needed to use the technique. For example, for the scale "static strength", the seven-point scale goes from "requires little force to move a light object" to "requires use of all the force possible to lift, push or pull a very heavy object". The specific task examples given on this seven point scale run from "push an empty shopping cart" (level 1 on the scale) to "load five full 50-gallon drums onto a truck (which appears at level 6 on the seven-point scale). In observing a new job, the rater looks at the tasks involved and places the job somewhere on the scale with respect to the definitions and examples given. The same is done for each of the nine scales covering the physical abilities described (Fleishman & Hogan, 1978).

It is clear to see that there are many ways of gathering job analysis information. There are task inventories and checklists and interviews with incumbents, with supervisors and with people who train people for the jobs (Fleishman, 1979; Jackson, 1994; Shrey & Lacerte, 1997; Toeppen-Sprigg, 2000). There are critical incident techniques which focus on those aspects of the job judged particularly relevant to effective or ineffective performance on the job (Fleishman, 1979; Shrey & Lacerte, 1997; Toeppen-Sprigg, 2000) and many more. The technique one uses depends to a great extent on the specific purpose. It is usually useful to employ as many information sources as possible to develop a complete information framework before advancing to any further steps (Fleishman, 1979; Toeppen-Sprigg, 2000).

2.4. Important considerations in developing job-related physical assessments:

After a proper and complete job analysis has been done, the next step is to produce a test battery that is safe, valid, reliable, objective, credible, and standardised (Shrey & Lacerte, 1997). Let`s firstly take a look at these critical terms.

2.4.1. Safety:

The safety of the individual must be of primary concern to the assessment administrator. 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 the testing procedure caused an injury and, therefore, are entitled to additional compensation (Shrey & Lacerte, 1997).

2.4.2. Validity:

Internal and external test validity issues must be identified and resolved when designing a test battery. Internal validity deals with whether the assessment 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).

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 as well as 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).

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). Criterion validity uses some standard or criterion that is known to indicate a single construct within a task accurately (McBurney, 1994; Neuman, 1997).

Hubbard *et al.* (1975) describes a common-sense method of developing job-related strength and agility tests based on a content validity strategy. Their procedure consists of five basic steps:
(1) task identification;
(2) rating of tasks for strength and agility factors;
(3) review of possible tests to be recommended;
(4) preliminary choice and try-out of the battery of tests; and
(5) preparation of a job relatedness analyses of the recommended tests.

2.4.3. Reliability:

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). 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).

2.4.4. 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). 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).

The collection of subjective data can also be of significant value. 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). Great care must be taken in providing guidelines for the collection and interpretation of this data (Shrey & Lacerte, 1997).

2.4.5. 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 submaximal 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 procedure 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).

2.4.6. 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). The oral instructions, task demonstrations, subject placement, and data collection and 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).

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 (as was the case in this study). Much of the original work in this area has been spearheaded by Chaffin (1974); Park & Chaffin (1975), Chaffin *et al.* (1977), Chaffin *et al.* (1978), Herrin & Chaffin (1978) and Keyserling *et al.* (1980). Their approach is based on two assumptions. First, 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 assumption (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) that do not agree and prefer different approaches to injury prevention.

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). Cut-off scores are often used on these strength tests, and they are usually set to approximate the maximum or near maximum requirements of the job. Biddle and Sill (1999) discuss 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).

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).

Many efforts at assessing human strength focus on static (isometric) strength. 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 standardized 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 the criteria by themselves. 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).

The variety of assessment techniques available for the measurement of human strength has created many problems. For example, Kroemer (1970) has pointed out that problems such as scoring differences, no controls for motivation, and poor measuring devices make comparisons across studies difficult. This, of course, increases the care that must be taken in order to demonstrate the content validity of selection procedures based on strength measurement.

A frequently heard criticism of strength testing is that it might expose the subject to safety risks such as pulled muscles or lower-back injuries. However, strength testing rarely results in injury to the subject. This could be explained by the receptors in the musculoskeletal system that senses the degree of strain and notifies the central nervous system when strain is occurring. When the strain is above learned limits, the voluntary action is stopped before injury. These learned limits provide a check on maximum efforts (Park & Chaffin, 1975; Campion, 1983). Fear of injury (conscious or unconscious) can, however, influence the performance of an individual. All methods of lifting assessment incorporate psychophysical limits (Shrey & Lacerte, 1997).

Another approach to the measurement of physical abilities derives from the work of Fleishman (1964 and 1979). Based on programmatic experimental-correlation studies of actual performance of subjects on a wide range of physical tests, nine physical fitness factors that can be measured via ten physical fitness tests were identified

(Fleishman, 1979; Magill, 1993; Jackson, 1994). There are two unique aspects about this approach. First, this assessment approach attempts to measure a wide variety of physical abilities including endurance, many types of strength, and measures of flexibility, co-ordination and balance (Jackson, 1994). Second, 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).

It might be noted that some research efforts have been devoted to predicting physical abilities based on other information. For example, Mital and Ayoub (1980) predicted strength and lifting capacity from anthropometric characteristics such as weight, shoulder, height, and chest depth. Gunderson *et al.* (1972) explored biographical and health status measures along with fitness to predict stressful physical performance. Body fat has also been used to predict gross motor proficiency (Brady *et al.*, 1977). All and all it has to be said that although these measures may correlate with physical abilities to some extent, it may be more logical and legally defensible to measure the actual physical abilities directly (Campion, 1983).

If one takes a look at the measurement of the strength requirements of jobs, it is clear that it can range from quite simplistic to very complex. At the most simple level one could merely weigh or rate the materials or equipment that the worker must lift. Along with recordings of heights lifted, transport distances, frequencies, etc., this approach can result in a reasonable picture of the strength requirements of the job (Campion, 1983). On a more sophisticated level, Chaffin (1974) and Chaffin *et al.* (1977) have developed a lifting strength (LSR) rating system. This system takes into account not only the weight of the load, but also the load location effect. The basis of this system is that it recognises the fact that if a load is held away from the body, the stress effect of the load is much greater. Each task is given an LSR rating which reflects the load lifted on the job compared to an estimated maximum human strength in the same position. In other words, each task is rated in terms of the proportion of a large, strong man`s strength required to perform it.

On an even more sophisticated level, Chaffin *et al.* (1977) has developed a computerised biomechanical strength model. Inputted into this model are body angles, weights, load locations, and normative population strength statistics. The model is then used to predict the proportion of men or women who could be expected to be able to perform the task.

Fleishman`s work on developing taxonomies and measures of human physical abilities has also resulted in a system for measuring the physical requirements of jobs (Theologus *et al.*, 1973; Dunnette, 1982; Hough *et al.*, 2001). With this approach, called Physical Abilities Analysis, one uses behaviourally anchored rating scales which are specifically constructed to assess the nine physical fitness abilities identified in the taxonomic research (Jackson, 1994). Further advances in this taxonomy have added scales for strength factors specific to the lower and upper body (Myers *et al.*, 1979). Fleishman eventually provided a comprehensive abilities taxonomy and methods for describing any job in terms of 37 different abilities (Dunnette, 1982). The advantages of using this approach for the measurement of physical requirements of jobs are that the scales are easy to use in a field setting, they cover a wide spectrum of physical abilities, they link physical abilities to job tasks, they relate to known abilities that can be tapped by specific tests, and they are supported by research and a solid theoretical background. However, one should not rely exclusively on ratings by incumbents, supervisors, or analysts. These job expert opinions should be combined with some of the more direct methods of assessing the physical requirements of physical jobs (Campion, 1983; Jackson, 1994).

It is clear that when measuring the physical requirements of jobs, one can look at a variety of options. Another approach that has ignited considerable interest is the development of perceived effort rating scales that actually relate to physiological workload (Campion, 1983; Jackson, 1994; Shrey & Lacerte, 1997). Most prominent in this area is the work of Borg (1962). He has developed a 15-point rating scale of perceived effort (RPE) specifically designed for use during bicycle ergometer work. This scale has shown high relationships to various metabolic indices such as heart rate (Campion, 1983; Jackson, 1994; Shrey & Lacerte, 1997). Hogan and Fleishman (1979) has shown that trained and untrained analyst ratings of written task statements on a Borg-type scale can be reliable and correlate well with actual metabolic costs of such tasks. Ratings such as these can also be used by subjects performing tasks to predict actual physical work (Hogan *et al.*, 1980; Jackson, 1994). They also showed that such task ratings could be used to classify diverse jobs according to physical effort requirements (Campion, 1983).

Up to now we have looked at quite a wide variety of different approaches and things to consider when looking at job-related physical assessments and the implementation there-of. There are however also a number of less obvious aspects that deserves attention. A few of these aspects can be recognised when Keyserling *et al.* (1980) lists the advantages of strength testing programs. They state that there usually exists a direct relationship to the job requirements, that can be reliably administered, that is predictive of injury rates, that is safe to use, easy to administer, and inexpensive.

Davis and Dotson (1987) takes a long hard look at age, and more specifically, advancing age as a factor that is associated with the loss of a number of fitness dimensions or components. It is commonly thought that older individuals are bound to fare poorly, and therefore will be treated unfairly, when physical abilities are tested as an inherent requirement of a job (Davis & Dotson, 1987; De Zwart *et al.*, 1995). Davis and Starck (1980) however, states that muscular strength doesn`t show significant changes over the employment years of adult males in law enforcement and fire fighting. In a study conducted by Petrofsky and Lind (1975), it was noted that older individuals were just as strong as their younger counterparts. Further studies have demonstrated that even untrained subjects can maintain relative muscular endurance up to the age of 65 years (Lemon & Hermiston, 1977). Davis and Dotson (1987) maintain that there exists ample evidence that older professionals in physically demanding jobs can successfully execute their duties. It follows that, as a group, older individuals who are otherwise healthy can modify their lifestyles, with particular emphasis given to physical activity, to develop and maintain the necessary physiological profile to successfully execute the duties of physically demanding jobs (Davis & Dotson, 1987; De Zwart *et al.*, 1995).

All and all the same principle applies for both females and males of all ages: If a job requires certain physical standards to be met in order to perform the tasks properly and safely, no exceptions can be made on account of age or gender. The job stays the same. The employer should be looking for people that fit the job, not the other way around.

As we near the end of this section, one might ask about the physiological considerations involved in physical ability testing. Although a later section is completely devoted to this very topic, it might be fitting to take a short look at what Campion (1983) had to say about it. He gives a simplistic summary of the physiological factors to consider before deciding what to test and how to test it. He explains that the ability to perform physical work depends on the ability of the muscle cells to transform chemically bound energy in food into mechanical energy for muscular work. This depends in turn on the capacity of the service functions that deliver fuel and oxygen to the muscles, including both oxygen uptake and cardiac output (Astrand & Rodahl, 1977; Arnheim & Prentice, 1993; Corbin & Lindsey, 1994). Additionally, other factors affecting physical performance capacity include the nature of the work itself such as intensity and duration, somatic factors such as sex and health, psychological factors such as attitude and motivation, environmental factors such as altitude and temperature, and other factors such as training and adaptation levels (Campion, 1983).

In most types of gross muscular exercise, oxygen uptake increases roughly linearly with increases in workload (Astrand & Rodahl, 1977; Arnheim & Prentice, 1993; Fox *et al.*, 1993; Corbin & Lindsey, 1994). Consequently, an individual`s maximum oxygen uptake (maximum aerobic power), has often been used as a direct index of the individual`s physical work capacity (Astrand & Ryhming, 1954). One approach in selecting for physically demanding jobs is to measure the workload, and then to only select people whose maximum aerobic power is great enough so that they can perform the job without excessive physiological fatigue. It is generally believed that a job should not require more than 30 to 40 % of an individual`s maximum aerobic power on a continuous basis during a normal 8-hour shift with usual breaks and rest pauses (Michael *et al.*, 1961; Astrand & Rodahl, 1977; Garg *et al.*, 1978; Konz, 1979). Therefore, this suggests a selection strategy of hiring only those individuals whose maximum aerobic power is two and one-half times greater than the continuous work load required on the job. Craig *et al.* (1998) evaluated the correlation between injury occurrence and aerobic capacity assessment and found that high occurrences of injury were significantly correlated with low relative maximal aerobic capacity. This proves that aerobic capacity testing definitely has a place in job-related physical assessments.

That concludes a section that will probably provide more questions than answers, but each of these questions are vital in the process of establishing and implementing a battery of job-related physical assessments that is tailor made for the job.

2.5. Methods and devices for measuring strength:

Human strength exertion capability is a very important consideration in the development of ergonomic guidelines for the screening of workers performing manual materials handling jobs (Karwowski & Mital, 1986). 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.*, 1980; 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). 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), and Foss & Keteyian (1998), all state that in a physiological sence, 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 showed no significant correlation between isotonic (dynamic) and isometric (static) measurements of strength gains (De Vries, 1986; Karwowski & Mital, 1986).

Krüger and Jansen van Vuuren (1998) gives a good summary of the advantages and disadvantages associated with the three major types of strength testing (isometric-, isotonic- and isokinetic strength testing). They also give a few examples of testing devices that can be used when administering these tests:

2.5.1. Advantages of isometric strength testing:

(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 (Krüger & Jansen van Vuuren, 1998).

2.5.2. Disadvantages of isometric strength testing:

(1) Tests are not specific enough to determine the changes due to an isotonic- or isokinetic exercise program.

(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 (Krüger & Jansen van Vuuren, 1998).

2.5.3. Devices for isometric strength testing:

(1) Dynamometers (e.g. grip strength dynamometer) (McArdle *et al.*, 1996; Krüger & Jansen van Vuuren, 1998; Erasmus, 1999; Powers & Howley, 2001).

(2) Cable tensiometry (McArdle *et al.*, 1991; McArdle *et al.*, 1996; Powers & Howley, 2001).

2.5.4. Advantages of isotonic strength testing:

(1) Produces objective documentation of test results.

(2) Tests can be administered in the laboratory or in the field (Krüger & Jansen van Vuuren, 1998).

2.5.5. Disadvantages of isotonic strength testing:

(1) The subject might have to be trained in a certain movement.

(2) The use of momentum during execution might lead to injuries (Krüger & Jansen van Vuuren, 1998).

2.5.6. Devices for isotonic strength testing:

(1) Gymnasium apparatus (e.g. 1RM bench press) (McArdle *et al.*, 1991; McArdle *et al.*, 1996; Krüger & Jansen van Vuuren, 1998; Powers & Howley, 2001).

2.5.7. Advantages of isokinetic strength testing:

(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 (Krüger & Jansen van Vuuren, 1998).

2.5.8. Disadvantages of isokinetic strength testing:

(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 (Krüger & Jansen van Vuuren, 1998).

2.5.9. Devices for isokinetic strength testing:

(1) Electromechanical apparatus (e.g. Cybex Norm) (McArdle *et al.*, 1991; McArdle *et al.*, 1996; Krüger & Jansen van Vuuren, 1998; Powers & Howley, 2001).

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

2.5.10. 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).

2.5.11. 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 is depressed over which the cable passes. 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).

2.5.12. 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).

2.5.13. 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).

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 of uniform duration and intensit;.
(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).

Chaffin *et al.* (1978) laid down specific criteria to be considered when developing strength tests and strength test batteries for the assessment of work-related physical ability:

(1) any testing procedure must be safe. This criterion precludes having people attempt to lift heavy objects (i.e., bar bells, steel bars, etc.), since this type of action would expose an individual to the hazards of both dropping the object onto a body part and imposing dynamic stresses on the body. It is generally accepted that isometric tests are safer to perform. In such tests a person simply increases the forces exerted on a static object to the level felt to be his/her maximum volitional force producing capability. The static object can be a handle (depending on the test) that is attached to a load cell or dynamometer which then measures the forces exerted and through an electronic display device allows the test supervisor to record the peak forces (Chaffin *et al.*, 1978);

(2) any test used must be a "reasonable" simulation of the strength requirements of the job. Two very important considerations here are movement simulation and location of the load (a person may be able to lift 100 pounds when held in close to the body, but only 20 pounds when held at arms length) (Chaffin *et al.*, 1978);

(3) any such test must be easy to perform. Ease of performance is best guaged by the time required for administration. Reduction of the number of tests to be performed in a test battery will ensure that less time is required (Chaffin *et al.*, 1978); and

(4) finally, all tests should be reliable. Repeatability of test results is one very important factor here. Ease of performance also plays a role in reliability as previous experience does not come into play that much and the results are more likely to be a true reflection of actual strength (Chaffin *et al.*, 1978).

2.6. Important physiological components involved in physical ability testing:

During and after any kind of physical activity, changes occur at a physiological level and physical labour is no exception. It is therefore of vital importance that the physiological components of physical ability testing are also looked at and understood. The following components are of critical importance during physical ability analysis / testing and the most relevant in terms of this dissertation: muscular strength; muscular endurance; flexibility; and cardiovascular fitness. Due to the natural onset of muscle fatigue, following physical activity, it will also be discussed.

2.6.1. 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). Hough *et al.* (2001) defines muscular strength as the ability to apply or resist force through muscular contraction.

The different types of muscular contraction have already been mentioned and defined, but an in depth look into the physiology and biomechanics that underlies these contractions seems both appropriate and necessary at this stage.

2.6.1.1. 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). 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:

(1) the initial length of the muscle fibers;

(2) the angle of pull of the muscle on the bony skeleton; and

(3) the speed of shortening (Fox *et al.*, 1993; Foss & Keteyian, 1998).

2.6.1.1.1. 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).

2.6.1.1.2. 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, such as joints and body contours, together 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).

2.6.1.1.3. The speed of shortening

There are three basic types of muscle fibers:

(1) slow-twitch oxidative fiber;

(2) fast-twitch oxidative-glycolytic fiber; and

(3) fast-twitch glycolytic fiber (Guyton, 1991; Arnheim & Prentice, 1993; McArdle *et al.*, 1996).

Fast twitch fibers are basically anaerobic. In contrast, slow-twitch fibers are aerobic. Fast-twitch fibers are responsible for speed or speed-power activities, such as sprinting or lifting heavy objects. Slow-twitch fibers come into play in endurance activities. The fast-twitch oxidative-glycolytic fiber lies somewhere in the middle, but closer to the fast-twitch glycolytic fiber than to the slow-twitch oxidative fiber (Guyton, 1991; Arnheim & Prentice, 1993; McArdle *et al.*, 1996).

At any given velocity (speed) of movement, the torque (the product of force x the lever arm distance) produced is greater the higher the percentage of distribution of fast twitch (FT) fibers 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 fibers. These relationships point out that FT fibers are capable of producing greater peak muscular tension and a faster rate of tension development than are ST (slow twitch) fibers (Fox *et al.*, 1993; Foss & Keteyian, 1998). The biochemical and physiological properties related to these contractile dynamics are the fiber`s myosin ATPase activities and their rates of calcium release and uptake from the sarcoplasmic reticulum. Both of these properties are higher within the FT fiber than in the ST fiber (Guyton, 1991; Fox *et al.*, 1993; Foss & Keteyian, 1998).

2.6.1.2. 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). 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).

2.6.1.3. Eccentric contraction:

Eccentric contraction refers to the lengthening of a muscle during contraction (i.e., during the development of active tension). 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).

2.6.1.4. 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). Such contractions are common during sports performances such as the arm stroke during freestyle swimming. The application of full tension during sports performance 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).

Now that we have a good grasp of the different types of muscular contractions, let`s take a look at the physiological changes that accompany increased strength in an individual. Muscular exercise is such a common experience that the more striking effects are evident to all. Muscle enlargement with a corresponding increase in strength is a common phenomenon and it was in fact first shown scientifically as early as 1897 (Fox *et al.*, 1993; Foss & Keteyian, 1998).

The enlargement of muscle that results from weight-training programs is mainly due to an increase in the cross-sectional area of the individual muscle fibers. This increase in fiber diameter is called "hypertrophy" and a reduction in size is called "atrophy" or "hypotrophy" (Vander *et al.*, 1990; Guyton, 1991; Fox *et al.*, 1993; McArdle *et al.*, 1996; Foss & Keteyian, 1998). In untrained muscle, the fibers vary considerably in diameter. The objective of a strengthening exercise program can be thought of as to bring the smaller muscle fibres up to the size of the larger ones. Rarely do the hypertrophied fibers exceed the cross-sectional area of the already existing larger ones, but a great many more attain this size. There exists a direct relationship between increased strength of a muscle and an increase in its cross-sectional area. This is the same for men and women (Fox *et al.*, 1993; McArdle *et al.*, 1996; Foss & Keteyian, 1998; Powers & Howley, 2001).

Hypertrophy of individual muscle fibers is attributable to one or more of the following changes:
(a) increased number and size of myofibrils per muscle fiber;
(b) increased total amount of contractile protein, particularly in the myosin filament;
(c) increased capillary density per fiber; or
(d) an increased amounts and strength of connective, tendinous, and ligamentous tissues (Guyton, 1991; Fox *et al.*, 1993; Foss & Keteyian, 1998).

The changes that contribute most to hypertrophy following weight-training programs are probably the first three points listed previously. Also, an increased number of capillaries per fiber are likely to be most closely associated with increased muscular endurance (Fox *et al.*, 1993; Foss & Keteyian, 1998).

Another interesting phenomenon is the finding of longitudinal fiber splitting in chronically exercised (weight lifting) animals. For many years the increased size of a muscle, as a result of weight training, has been attributed solely to an increase in the diameter of the muscle fibers already present (hypertrophy), and not to an increase in the number of fibers (hyperplasia). Observation of fiber splitting, of course, casts some doubt on earlier theories about increases in muscle size. Fiber splitting has been shown in several different animals, following high-resistance programs (e.g., rats and cats). It has, however, not as yet been shown to occur in humans following weight-training programs. In fact, more recent studies indicate that increases in the size and strength of human muscles are related to muscle fiber hypertrophy rather than hyperplasia as a result of fiber splitting (Fox *et al.*, 1993; McArdle *et al.*, 1996; Foss & Keteyian, 1998; Powers & Howley, 2001). Guyton (1991), however, states that a very few greatly enlarged muscle fibers in humans are believed to split down the middle along their entire length to form new fibers, thus also increasing the numbers of muscle fibers slightly and contributing to the hypertrophy of a muscle.

On a biochemical and muscle fibre compositional level, a number of changes have also been shown to occur in skeletal muscle following weight training programs:

(1) increases in concentrations of muscle creatine (by 39%), PC (by 22%), ATP (by 18%), and glycogen (by 66%);
(2) increase or no change in glycolytic enzyme activities (phosphofructokinase; lactate dehydrogenase; muscle phosphorylase; and hexokinase);
(3) little or no consistent change in the ATP turnover enzyme activities, such as myokinase and creatine phosphokinase;
(4) small but significant increases in aerobic, Krebs Cycle enzyme activities (e.g. malate dehydrogenase and succinic dehydrogenase);
(5) no interconversion of fast- and slow-twitch fibers;
(6) a decrease in the volume (density) of mitochondria due to increases in size of the myofibrils and the sarcoplasmic volume;
(7) increase in mitochondrial enzymes;
(8) increase in stored glycogen;
(9) a selective hypertrophy of fast-twitch fibers as evidenced by an increase in the FT:ST fiber area; and
(10) an increase in stored triglyceride (Guyton, 1991; Fox *et al.*, 1993; McArdle *et al.*, 1996; Foss & Keteyian, 1998).

Two major conclusions seem warranted based on the previous changes. First, the biochemical changes are small and for the most part inconsistent. Therefore, it is highly likely that other changes are mostly responsible for improved muscle function following weight training. Although these other changes have not been precisely identified, they probably involve adaptations within the nervous system, including changes in the recruitment pattern and synchronisation of motor units. Second, it appears that a high percentage of distribution of fast-twitch fibers is a prerequisite for maximal gains from strength training programs. This is suggested by the selective hypertrophy of fast-twitch fibers, which reflects their preferential use during strength-training exercises. In addition, the increase in isotonic strength per unit of muscle cross-sectional area is positively correlated with the percentage of distribution of fast-twitch fibers. This relationship may also help explain why the individual response to training varies considerably (Fox *et al.*, 1993; Foss & Keteyian, 1998).

2.6.2. Muscular endurance:

Corbon & Lindsey (1994) and Hough *et al.* (2001) describes 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). 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).

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).

There tends to be a corresponding increase in muscular endurance as muscle strength increases, albeit small (Arnheim & Prentice, 1993; Corbin & Lindsey, 1994). Endurance training is however very specific and people who is strength-trained will fatigue as much as four times faster than a person who is endurance-trained (Corbin & Lindsey, 1994). Muscle endurance is also specific to the muscles being used, the type of muscle contraction (static or dynamic), the speed or cadence of the movement, and the amount of resistance being used. Therefore it is true that a muscular endurance training program should always apply the principle of specificity by closely resembling the activity for which the endurance is needed (Corbin & Lindsey, 1994).

Muscular endurance training tends to develop the slow-twitch fibers in your muscles. As you train specifically for muscular endurance, the muscles adapt as a result of changes in slow-twitch fibers, including increased activity of aerobic enzymes in the muscle itself. The reason for these changes are that muscular endurance training usually consists of high repetitions with low loads as apposed to the low repetitions and high loads used in strength training (Corbin & Lindsey, 1994; Powers & Howley, 2001).

2.6.3. 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. Studies have indicated that an increase in the flexibility of inflexible joints tends to decrease the injuries to those joints (Arnheim & Prentice, 1993).

Plowman and Smith (1997) explains 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), and Foss & Keteyian (1998), 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).

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).

To increase the length of a muscle, you must stretch it (overload) more than its normal length. Evidence suggests that muscles should be stretched to about 10% beyond their normal length to bring about an improvement in flexibility. Exercises that do not cause an overload by stretching beyond normal will not increase flexibility (Corbin & Lindsey, 1994). There are generally three methods of stretching, namely:
(1) static stretching (a form of stretching in which the muscle to be stretched is slowly put into a position of controlled maximal or near-maximal stretch and held in that position for a given amount of time);
(2) dynamic stretching, also referred to as "ballistic" stretching (a form of stretching, characterised by an action-reaction bouncing motion, in which the joints involved

are placed into extreme range of motion limits by fast, active contractions of agonistic muscle groups); and

(3) proprioceptive neuromuscular facilitation, also referred to as "PNF" stretching (a stretching technique in which the muscle to be stretched is first contracted maximally, after which the muscle is relaxed and then either actively stretched by contraction of the opposing muscle or by passive stretching) (Powers & Howley, 1994; Plowman & Smith, 1997; Foss & Keteyan, 1998).

Although all three types of stretching will improve flexibility, the static method might be preferred, because:

(1) there is less danger of tissue damage;
(2) the energy requirement is less; and
(3) there is prevention and/or relief from muscular distress and soreness (Foss & Keteyan, 1998).

In static stretching, the rate of change in muscle length is slow as the individual gets into position and then is non-existent as the position is held. Because of this, the annulospiral nerve endings of the neuromuscular spindle are not stimulated to fire and a strong reflex contraction does not occur. This is because the dynamic phase of the neuromuscular spindle response is bypassed. Instead, if the stretch continues for at least 6 seconds, the Golgi tendon organs respond, leading to the inverse myotatic reflex and causing relaxation in the stretched muscle group. This response is called autogenic inhibition. This relaxation is easily felt by the exerciser, and it allows the muscle to be elongated even further (Plowman & Smith, 1997). The impulses from the Golgi tendon organs are able to override the weaker static response impulses coming from the neuromuscular spindle to allow this reflex relaxation and a continuous sustained stretch (Plowman & Smith, 1997; Powers & Howley, 2001). Ultimately, the muscle being stretched will reach a point of myoclonus (twitching or spasm in the muscle group) indicating the endpoint of an effective stretch (Plowman & Smith, 1997).

2.6.4. Cardiovascular fitness:

Corbin & 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), defines cardiorespiratory fitness as the ability to deliver and use oxygen under the demands of intensive, prolonged exercise or work. 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).

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). Aerobic exercise is the preferred method for improving cardiovascular fitness. It can be defined as 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". 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 program is capable of increasing VO_2 max to its highest limit within the inherited range. 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).

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 lets take a closer look at each one of these contributing factors to see how they contribute to cardiovascular fitness and how we can improve the way they function:

(1) The heart. The heart is a muscle. To become stronger it 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).

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 fibers. 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).

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 result in a failure to remove used blood at the proper rate. As a result, venous blood pools, especially in the legs, causing a condition known as varicose veins (Fox *et al.*, 1993; Corbin & Lindsey, 1994; McArdle *et al.*, 1996; Foss & Keteyian, 1998).

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).

(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. 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).

Delivering oxygen to the tissues from the blood is called internal respiration. 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).

(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 fibers. These fibers, when trained, undergo changes that make them especially able to use oxygen. Outstanding distance runners often have high amounts of ST fibers and sprinters often have high amounts of FT muscle fibers (Fox *et al.*, 1993; Corbin & Lindsey, 1994; McArdle *et al.*, 1996; Foss & Keteyian, 1998).

2.6.5. 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). 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 fibers within the motor units to transmit nervous impulses;

(2) the neuromuscular junction to relay the nervous impulses from the motor nerve to the muscle fibers;
(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 (Vander *et al.*, 1990; Fox *et al.*, 1993; Plowman & Smith, 1997; Foss & Keteyian, 1998).

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).

2.6.5.1. 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 fibers compared with ST fibers. Failure of the neuromuscular junction to relay nervous impulses to the muscle fibers is most likely due to a decreased release of the chemical transmitter, acetylcholine, from the nerve ending (Vander *et al.*, 1990; McArdle *et al.*, 1991; Fox *et al.*, 1993; Plowman & Smith, 1997; Foss & Keteyian, 1998).

2.6.5.2. Fatigue within the Contractile Mechanism:

Several factors have been implicated in fatigue of the contractile mechanism itself. Here follows some of them:

(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 fibers produce more lactic acid in comparison with ST fibers. This greater ability to form lactic acid might be one contributing factor to the higher anaerobic performance capacity of the FT fibers. 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 fibers 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 (Vander *et al.*, 1990; Meyer & Meij, 1992; Fox *et al.*, 1993; McArdle *et al.*, 1996; Foss & Keteyian, 1998).

(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 (Vander *et al.*, 1990; Fox *et al.*, 1993; Foss & Keteyian, 1998; Powers & Howley, 2001).

(3) Depletion of Muscle Glycogen Stores. During prolonged exercise the muscle glycogen stores within some of the fibers (mainly ST fibers) 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). 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 fibers. 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).

2.6.5.3. 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 (Vander *et al.*, 1990; Fox *et al.*, 1993; Foss & Keteyian, 1998). 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 & Meij (1992) explains 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 fibers are unable to relax.

2.7. Pre-placement assessment and the legal side of things:

The Labour Relations Act 66 of 1995 and the Employment Equity Act 55 of 1998 have a marked effect on the hitherto unprotected position of job applicants. Employers suddenly find themselves in a position where they can be subjected to litigation by unsuccessful job applicants on the basis of unfair discrimination. This new development impacts on various aspects of recruitment not least of which is the medical screening of applicants (which can include physical ability testing). Occupational health professionals share in the responsibility to guard against practices that may cause such a liability. It is therefore imperative that they are familiar with the possible legal repercussions of their activities as it relates to pre-placement testing (Botha *et al.*, 1998).

Occupational health professionals have a significant role to play in the selection of suitable employees as well as in the management of incapacitated employees (Hogan & Quigley, 1986; Strasheim, 1996; Van Niftrik, 1996; Botha *et al.*, 1998; Botha *et al.*, 2000). Both of these areas can have serious legal implications and the Labour Relations Act looks closely at both of them. In terms of this dissertation, however, 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. A broad interpretation may include disabled or medically impaired persons.
- 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.
- Schedule 7, item 3(3) of the Act determines that labour disputes regarding unfair discrimination will be referred to the Commission for Conciliation, Mediation and Arbitration for conciliation. If unresolved, the matter will be referred to the Labour Court for final determination.

- Schedule 7, item 2(2)(a) of the Act determines that the Labour Court, in such cases, may make any award it deems appropriate, including an award for compensation (Labour Relations Act 66, 1996; 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 Employee Equity Act, will obviously substantiate a claim of unfair discrimination. The issue may be even more problematic where a medical 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 whilst 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).

It is imperative for the employer to be able to conclusively show, not only that the medical 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).

Now that some light has been shed on pre-placement assessment and the legislation involved, let`s 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 a medical 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. Tests should not be superfluous or arbitrary in nature as to risk a *prima facie* indication of discrimination. For example, a strength test battery may be essential in screening applicants as potential powerline workers. 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, 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).

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).

Certain biokinetic activities can enhance the pre-placement process in terms of the following:

- setting physical norms of specific job categories (occupational risk exposure profile) and the assessment of the applicant;
- physical selection for work placement; and
- advice on work adaptations in the event of job reservation for disabled employees as result of a practice designed to protect/advance previously disadvantaged persons (Botha *et al.*, 1998).

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).

2.8. Pre-placement assessment and the prevention of work-related injuries:

Traditional "experts" on physical ability testing, such as Chaffin (1974) and Chaffin *et al.* (1978), have always supported the concept that the incidence and severity of musculoskeletal illness or injury can be reduced on jobs that require physical exertions. Through the years it has been proposed that such a reduction can be achieved by selectively employing workers who can demonstrate strengths in standardised tests which are as great or greater than that required in the normal performance of their jobs (Chaffin, 1975). In the course of this type of research, many basic and practical questions have been raised. Some of these questions have been answered sufficiently, most of them are still being debated (Waddell & Burton, 2001).

One point that is not debated, however, is the ever rising incidence of disability among the working population, in South Africa and abroad (Chavalinitikul *et al.*, 1995; Van Niftrik, 1996). Millions of rands/dollars are lost every year due to worker`s compensation claims (Lukes & Bratcher, 1990; Malan & Kroon, 1992; Greenberg & Bello, 1996). Low 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), accute 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.

Various approaches have been followed in an attempt to curb the alarming increase in disability claims worldwide. Review of the literature reflects the notion that prolonged rest and conventional physical therapy are not effective in the treatment of the chronic sufferer (Leavitt, 1992; Greenberg & Bello, 1996). Newton & Waddell (1993) did a review of the scientific literature on "iso-machines" (isokinetic- and isoinertial testing) as a method of testing dynamic trunk strength and the relation to low back pain. They found that there was inadequate scientific evidence to support the use of "iso-machines" in preemployment screening, routine clinical assessment and medico-legal evaluation.

Carmean (1998) also takes an in depth look at how preplacement strength testing programs can be used to reduce back injuries among nursing home employees and find that certain strength testing programs can be used to good effect in reducing the incidence of back injuries. Jetté *et al.* (1992) states that on-site fitness assessments that include tests for strength, endurance and flexibility can be used as a diagnostic and intervention procedure that also serves as an excellent motivational and educational tool. Chavalinitikul *et al.* (1995) opted for a totally different approach when they undertook training courses, educating physical workers on the ergonomically correct ways of lifting and moving heavy objects. Regular follow-up studies suggested that back pain problems dramatically decreased since the training courses.

Garg & Moore (1992) identified two approaches as the most effective strategies in preventing low 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 low back injuries. They also state that ergonomic job design offers the most potential for preventing disabling injuries, but job-specific strength testing is supported as a means of identifying high-risk workers early. Van Niftrik (1996) gives five basic principles to consider in the assessment and management of disability:

(1) early diagnosis and consensus assessment;
(2) early intervention;
(3) motivational counselling;
(4) rapid rehabilitation; and
(5) stringent follow-up protocols.

Waddell and Burton (2001) did an extensive, systematic review of the literature on the management of low back pain at work. They categorised all the evidence statements on a system with four categories. All the evidence they presented fell in one of the following categories: (1) strong evidence; (2) moderate evidence; (3) limited or contradictory evidence; or (4) no scientific evidence. Here follows some of the relevant findings made by them:

(1) there is strong epidemiological evidence that physical demands of work (lifting, bending, twisting, etc.) can be associated with increased reports of back symptoms and injuries (Frymoyer *et al.*, 1983; Griffin *et al.*, 1984; Capodaglio, 1997; Hadler, 1997; Waddell & Burton, 2001);

(2) there is strong evidence that physical demands of work are a risk factor for the incidence of low back pain, but overall it appears that the size of the effect is less than that of other individual, non-occupational and unidentified factors (Burton, 1997; Waddell, 1998; Waddell & Burton, 2001);

(3) there is moderate scientific evidence that physical demands of work play only a minor role in the development of disc degeneration (Bartié et al., 1995; Videman & Bartié, 1999; Waddell & Burton, 2001);

(4) there is moderate evidence that examination findings, including in particular height, weight, lumbar flexibility and straight leg raising, have little predictive value for future low back pain or disability (Frymoyer, 1997; Waddell & Burton, 2001);

(5) there is moderate evidence that the level of general (cardiorespiratory) fitness has no predictive value for future low back pain (Frymoyer, 1997; Waddell & Burton, 2001);

(6) there is limited and contradictory evidence that attempting to match physical capability to job demands may reduce future low back pain and work loss (Garg & Moore, 1992; Frymoyer, 1997; Waddell & Burton, 2001);

(7) there is strong evidence that back-function-testing machines (isometric, isokinetic, or isoinertial) have no predictive value for future low back pain or disability (Newton & Waddell, 1993; Waddell & Burton, 2001); and

(8) there is contradictory evidence that various general exercise/physical fitness programmes may reduce future low back pain and work loss (Volinn, 1999; Waddell & Burton, 2001).

Waddell and Burton (2001) recognise the need for further studies on pre-placement assessment, particularly matching previous history of low back pain, physical capabilities and job demands.

Women now account for a larger percentage of the active work force than in earlier decades, and women are expanding into traditionally male-dominated trade and craft occupations. As a result of these trends, there are now more women in occupations that historically have had high injury rates (Davis & Dotson, 1987; Kelsh & Sahl, 1996). Studies within American postal services, trade, industry and the army have suggested that females are at a higher risk for occupational injuries or musculoskeletal problems based on medical statistics (Kelsh & Sahl, 1996). Possible explanations for these sex differences include the following:

(1) physical capacity differences exist between men and women;
(2) workplace designs are more appropriate for males than females;
(3) women have additional physical and stress demands due to parental and household responsibilities; and
(4) women are more likely to report injuries (Kelsh & Sahl, 1996).

Earlier in this section, Garg & Moore (1992) suggested that "job-specific strength testing" and "ergonomic job design" are the most effective approaches to the prevention of work-related injury. Explanations (1) and (2) for the high injury rates among female workers suggests that Kelsh & Sahl (1996) supports these views and the view of Davis and Dotson (1987) that the ever increasing number of women applying for physically demanding jobs puts pressure on employers to make use of some sort of pro-active approach to try and prevent injuries in the work place.

Shrey and Lacerte (1997) introduced a tool that can be used to assess an individual`s abilities to perform work-related tasks. It is simply called "FCA" (Functional Capacity Assessment) and it can be used for pre-placement assessment as well as for post-injury assessment to determine whether the employee is capable of resuming his/her normal tasks. The FCA consists of a battery of tasks specifically designed to directly measure an individual`s functional ability to perform specific tasks. This assessment allows the occupational health professional to determine an individual`s work ability based on physical performance, rather than the extrapolation of an individual`s abilities based on the methods of traditional medical diagnostics – x-ray, CAT scan, MRI, EMG, and various laboratory data. The primary goal of the FCA is to determine the working capabilities of an individual and, when possible, compare this with the physical demands of the job. These capabilities include high force, nonrepetitious tasks such as lifting, pushing, and pulling; low-force tasks such as repetitive movements; precision tasks such finger dexterity, and static and dynamic posture tolerances such as sitting, standing, and walking. The specific tasks performed in the FCA is determined by the purpose of the assessment (i.e., pre-placement or return-to-work post-injury).

It is clear that more research on the role of pre-employment testing in the prevention of work-related injuries is necessary as scientists still differ greatly in their opinions. It does seem, however, that most of them recognise the fact that pre-employment testing can assist to some extent. It is more the extent itself that is under debate.

2.9. Job-related physical assessment and the benefits to the company:

Any company is primarily concerned with the bottom line. In other words, they want to see improvement in productivity, accident rates, turnover rates, absenteeism, sick leave, ill-health applications, etc., simply because these concepts are directly related to the profits of the company. The implementation of any fitness program in the workplace, usually depends on management`s acceptance that the program will be financially worthwhile (Greenberg *et al.*, 1995; Finch & Owen, 2001). Borofsky and Smith (1993) indicated in a study that a preemployment screening inventory could result in significantly lower accident rates, turnover rates and absenteeism. Lubbe (2001) and Lubbe (2002) indicated that physical ability screening and subsequent intervention programs can result in higher productivity, as well as lower employee turn-over rates, less sick leave, and fewer ill-health applications.

A previous section focussed on the occurrence of work-related injuries and the magnitude of the problem and also provided several approaches that can be employed to try and reduce such occurrences. Malan (1992) states that methods have to be employed to try and fit the worker to the job, as this is associated with a reduction in work-related injury, with an improvement in worker productivity and with improved job satisfaction. According to Borofsky *et al.* (1995) and De Zotti *et al.* (1995), the physical screening of applicants for physical jobs leads to a number of benefits for both employee and employer. Some of the benefits they mention include a reduction in sick leave, a reduction in ill health applications, and improved productivity.

Lubbe (2002) showed that early risk identification through work-related physical assessments and early biokinetics intervention can hold significant benefits for a company. The figures shown in table 2.1 are based on risk identification/intervention programs employed within an electrification company during 2002.

Table 2.1: Benefits of risk identification/intervention programs employed within an electrification company during 2002:

Variable	% improvement
Average physical ability improvement of participants	11.7%
Average psychological improvement of participants	30.6%
Average attitude improvement of participants	33.1%
Average lifestyle habit improvement of participants	29.2%
Average cardiac risk reduction of participants	5.9%
Average participant improvement (supervisor perception)	24.7%
Average sick leave/absenteeism reduction of participants	11.5%

Meier (1998) lists some of the results that were reported by other companies that made use of preemployment physical screening programs:

(1) 45% reduction in back injuries;

(2) 53% reduction in all job-related injuries;

(3) 100% reduction in lost mandays;

(4) 64% reduction in worker`s compensation costs; and a

(5) 7.5% increase in productivity.

Jackson (1994) reports three studies that prove strength testing to be the most effective job placement technique for materials-handling tasks. All three studies looks at the potential value of pre-placement strength testing in preventing injuries at work as these injuries cost companies millions every year (Lukes & Bratcher, 1990; Malan & Kroon, 1992; Chavalinitikul *et al.*, 1995; Greenberg & Bello, 1996) in compensation claims, lost work days, lower productivity, etc. The first study showed that strength is related to injury rate and that a worker`s likelihood of sustaining a musculoskeletal injury increased when job lifting requirements approached or exceeded the worker`s strength capacity. The approach compared the worker`s strength with the strength required by the work task. Using 410 employees in 103 jobs, a significant relationship was found between the ratio of strength required on the job and the worker`s strength, and the incidence of low back injury during the year of the study (Jackson, 1994).

In a second study, with 551 employees from six plants, the likelihood of sustaining back injuries was a function of isometric arm, leg, and torso strength. As the strength demands of the job approached the subject`s maximum strength capacity, the chances of injury tended to increase. In a third study, a biomechanical analysis quantified the strength demands on production jobs in an aluminium reduction plant. The biomechanical data served as the model for designing strength tests that simulated the job activities with the greatest strength demands. A cross-section of employees assigned to the physically demanding jobs was strength tested and monitored for medical incidents for more than two years. The data analysis showed that workers with strength abilities below the job strength requirements suffered a significantly higher rate of medical incidents than workers whose strength matched or exceeded job demands (Jackson, 1994).

When looking at research results such as this, it comes as no surprise that huge savings are reported in companies that make use of work-related physical assessment programs (pre- or post-employment). Lukes and Bratcher (1990) reports that a pre-employment physical assessment approach by the state of Arizona in the U.S.A., for state jobs, showed savings of over $208 000.00 in worker`s compensation back injury claims. Lubbe (2001 & 2002) reports savings of R655 860.00 during 2001 and R2 354 498.41 during 2002 in an electricity supply company that uses physical ability screening and an early biokinetics intervention program. These programs showed annual returns on investment of R2.35 for every R1.00 invested by the applicable company in 2001 and R6.77 for every R1.00 invested in 2002. It is also estimated that 88% of all studies reduce medical care costs with an average saving of $3.35 per $1.00 invested and that 87% of all preventative programs reduce absenteeism with an average saving of $4.90 per $1.00 invested (Aldana, 1998).

Malan & Kroon (1992), as well as Lubbe (2002) refers to a very fitting statement made by a certain mister Stamper in 1987, referring to the prevention of work-related injuries: "We pay doctors and hospitals billions to nurse us back to health to continue with our work, but we spend peanuts in protecting ourselves against injury".