

The Effect of Work-Hardening on the  
Physical Work Capacity of Manual Labourers  
within South African Industry

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## ABSTRACT

South Africa is a labour-intensive industrially developing country. As a result, in excess of 200 000 workers suffer from musculoskeletal injuries in a year. Research is thus essential to develop more effective strategies in the reduction and rehabilitation of occupational musculoskeletal disorders within industry. It was the hypothesis of this study that by improving the physical work capacity of manual labourers, through participation in an occupation-specific work-hardening programme, that the **ergonomic stress index** and therefore the occurrence of musculoskeletal injuries within industry, may be reduced.

Twenty-five male Black and Coloured manual labourers volunteered to participate in this study. In addition to *in situ* task analyses, the subjects participated in cardiovascular and strength assessments in the laboratory, both pre- and post-participation in the ten-week work-hardening programme. The data were statistically analyzed in order to identify any significant improvements in the workers' physical work capacity, as measured by cardiovascular, strength and perceptual responses, following the period of work-hardening. Two significant reductions were noted in measures of working heart rate together with significant improvements in grip strength and trunk strength tested at a velocity of  $60^{\circ}.\text{sec}^{-1}$  at the post-conditioning assessments. In conclusion, the ten-week work-hardening programme resulted in nominal improvements in all the cardiovascular measures and significant improvements in the subjects' strength performance. However, industrialists must recognise that this study dealt with only one aspect of reducing the ergonomic stress index at the workplace and realise that, in addition to this focus, it remains essential to design the task to fit the human operator.

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## CHAPTER ONE

### INTRODUCTION

#### INTRODUCTION

In an industrially developing nation such as South Africa where manual materials handling is inherent within industry, manual labour involving physically demanding tasks, is a dominant factor. If indeed, as Genaidy *et al.* (1992) and Waters *et al.* (1993) recognize, it is the physical demand of many industrial operations, in particular manual materials handling, which is responsible for the greater percentage of musculoskeletal disorders, then one can only assume this to be especially true within the South African industrial scene.

Although in the past many work organisations worldwide have been negligent in their responsibilities to their employees, attributing accidents and musculoskeletal injuries to be unfortunate and inevitable consequences of work, today this notion is obsolete. Investigation and experience have both demonstrated that the frequency and gravity of occupational accidents and injuries can be reduced. However, despite significant improvements in working conditions, particularly within the developed countries, Frankel (1987) maintains that there is virtually no occupation that is devoid of potential health and safety risks. In reality, states Feuerstein (1991), the epidemiology of occupational disability and musculoskeletal disorders indicates that the problem is growing. The result is that the impact of occupational injuries, and the total cost in terms of disability, suffering and economic loss internationally, remains enormous.

Research is thus essential to develop more effective strategies in the prevention and rehabilitation of occupational disability worldwide. Given the extent of musculoskeletal injuries and illnesses relative to other occupational health problems it appears that it is the musculoskeletal system which is particularly vulnerable to injury. The National Institute for Safety and Occupational Health (NIOSH) has in fact identified musculoskeletal injuries as one of the ten leading occupationally-related health problems in the United States. Of these musculoskeletal injuries lower back pain represents a major component. Unfortunately these sort of statistics are not readily available in South Africa and other developing countries. According to Nordin (1987), the problem is however, presumed to be much greater in developing countries because manual labour is still so commonplace.

At the very core of this problem should exist a concern for the general health and well-being of the South African worker with occupational health being a specific consideration. According to Nordin (1987) and Shahnavaz (1987) workers should be seen as one of the most important sectors of the community with their general well-being considered an essential element in the economic and social development of the country as a whole. In South Africa especially, there is increasing concern about the slow growth of the economy. Economic progress is dependant on the level of industrialization and the rate of productivity, of which the human element is still the key, despite the sophistication of modern technology (Scott, 1993).

Genaidy *et al.* (1992) and Waters *et al.* (1993) believe that occupational musculoskeletal injuries are primarily of over-exertion in nature where the worker exceeds personal physical capability limits. Indeed, previous research has demonstrated that employee **physical**

incapacity is a contributing factor to the etiology of lower back pain and other musculoskeletal disorders resulting from manual materials handling (NIOSH, 1981; Asfour *et al.*, 1984; Kesley and Golden, 1988; Ayoub and Mital, 1989; Genaidy *et al.*, 1989; Genaidy *et al.*, 1994). These same studies indicate that improved physical conditioning plays an important role in the reduction of occupational injuries, particularly lower back pain, as well as occupational health care costs in industry. These authors believe that it is therefore possible that a general physical conditioning programme used as a prophylactic intervention may improve the physical work capacity of labourers in order to help them cope with physically demanding tasks, as well as reduce the period of disability of the worker accidentally exposed to musculoskeletal stress at the workplace. Such an intervention programme could consequently serve to reduce the amount of lost work time and resulting drop off in productivity as a result of occupational disability.

It is the proposal of the present project however, that the concern for increasing productivity, specifically within South Africa, should not be about making people work harder. As Greenborough (1980) suggests, management should be concerned with equipping, organising and motivating people to work more effectively. It is possible that this could be achieved through **work-hardening** programmes, a rehabilitative approach recently developed in the United States.

Work-hardening programmes attack the multifactorial problem of musculoskeletal injuries at work by creating an awareness of the importance of the human being as well as acknowledging the social, economic and international impact of occupational disability. Such an integrated approach argues for a broad consideration of occupational health not only

within a biomechanical and physiological framework, but also a psychosocial framework.

According to Greenberg and Bello (1996), work-hardening programmes therefore use a multifaceted approach to treat musculoskeletal injuries, demonstrating a concern for the general well-being of the worker. These programmes offer occupation-specific rehabilitation. Not only are the actual components of the individual's work integrated into the programme so that work-simulation becomes part of the specific strengthening and conditioning undertaken to meet distinctive occupational demands but, in addition, the psychosocial aspect of physically demanding situations is included allowing one to address the issues of behavioural responses in addition to physical tolerances. The psychosocial effect of disability is an area of increasing interest and reflects the recent growing awareness of the need to consider people in their totality and the need to take an holistic approach.

According to Isenbarger (1991), work-hardening programmes characterize rehabilitation in its most practical form with the functional outcome being an elevation of the worker's physical capacity to a previous or improved habilitation level. To date however, this approach has not been explored within a developing nation such as South Africa with its unique character and form, and where manual material handling is so predominant.

Further, it is possible that work-hardening programmes could amount to a form of primary health care within South Africa by being prescribed not only as a rehabilitative method but as a preventative measure within industry, in an attempt to proactively reduce the extent of musculoskeletal disorders. This idea can be explained through the concept of the **ergonomic stress index** defined by Genaidy *et al.* (1992) as the ratio of job requirements to employee

capabilities. In the past the emphasis has been on reducing the ergonomic stress index through reducing job requirements. However, it is possible that by improving physical work capacity through involvement in a prophylactic work-hardening programme, one may further reduce the ergonomic stress index and thus the incidence of musculoskeletal disorders and low-back pain.

There is an economic motive within South Africa to not only provide treatment, but to prescribe preventative measures. Instead of paying doctors and hospitals excessive amounts to return workers to health yet spending minimal to protect them against illness or injury, one should be encouraging individual health and well-being at work. This approach represents the other side of the coin to the traditional medical approach, with *physical work capacity* being seen as a very important variable within the equation of the overall health of the labour force. Promoting employee health and education as well as improved physical conditioning while at the same time reducing occupational disability would therefore seem an effective route to reduce absenteeism, improve productivity and enhance South African industries' abilities to compete internationally.

## **STATEMENT OF THE PROBLEM**

Internationally, but specifically in the developing countries, manual work is still performed by large sections of communities. In South Africa manual materials handling, in particular manual lifting, represents a major problem and possible cause of injury, specifically to the lower back, in industrial workers.

The concept of this research grew out of a need for more effective strategies in the prevention and rehabilitation of occupational disability, specifically within South Africa and other developing countries. The essence of the problem is a concern for the general health and well-being of the South African worker, and a need to address the negative economic consequences of occupational disability, particularly that of low-back pain.

## **RESEARCH HYPOTHESIS**

The general hypothesis of this study was that involvement in an occupation-specific work-hardening programme would improve the physical work capacity of the employees involved in the programme resulting in an improved ability of the South African worker to cope with the physical task demands of his job; biomechanically, physiologically and psychosocially. It was hoped that this in turn would reduce the onset of musculoskeletal disorders, specifically low-back pain, and/or the period of disability for the injured worker.

## **STATISTICAL HYPOTHESES**

The following overall null hypothesis was adopted:

It was hypothesized that no difference would exist in the physical work capacity of the subjects, as measured by cardiovascular, strength and perceptual responses, following participation in the ten-week work-hardening programme.

$$H_0 : \mu_{pre(pwc)} = \mu_{post(pwc)}$$

$$H_a : \mu_{pre(pwc)} \neq \mu_{post(pwc)}$$

The overall null hypothesis was sub-divided into three sub-hypotheses:

- 1) The null hypothesis states that there will be no difference in the cardiovascular condition of the subjects when assessed pre- and post-participation in a ten-week work-hardening programme.

$$H_0 : \mu_{pre(c)} = \mu_{post(c)}$$

$$H_a : \mu_{pre(c)} \neq \mu_{post(c)}$$

- 2) The null hypothesis states that there will be no difference between the physical strength measures of the subjects when assessed pre- and post-participation in a ten-week work-hardening programme.

$$H_0 : \mu_{pre(s)} = \mu_{post(s)}$$

$$H_a : \mu_{pre(s)} \neq \mu_{post(s)}$$

- 3) The null hypothesis states that there will be no difference in the perceptual responses of the subjects when assessed pre- and post-participation in a ten week work-hardening programme.

$$H_0 : \mu_{pre(p)} = \mu_{post(p)}$$

$$H_a : \mu_{pre(p)} \neq \mu_{post(p)}$$

where:

$\mu_{pre}$  is the mean value for male manual labourers prior to participation in a work-hardening programme.

$\mu_{post}$  is the mean value for male manual labourers following participation in a work-hardening programme.

and:

pwc = physical work capacity

c = cardiovascular measures

s = strength measures

p = perceptual responses

## DELIMITATIONS

The subjects for this study were Black and Coloured adult male volunteer manual labourers presently employed at one of three local Grahamstown industries.

An initial *in situ* task analysis was conducted in order to obtain a working understanding of the physical requirements of each individual's daily occupational tasks. The subjects were then assessed on two separate occasions in the Department of Human Movement Studies, Rhodes University; that is a pre- and post-conditioning assessment before and after the ten-week involvement in a work-hardening programme in order to measure any statistically significant differences that may have occurred in the subjects' physical work capacity as a result of their participation in the programme. These tests were administered at a time

convenient for both management and workers. A final *in situ* task analysis was conducted at the finish of the laboratory testing in order to note any improvements in the workers' execution and perception of their tasks. Situational risk assessments were also conducted prior to the subjects' participation in the work-hardening programme in order to obtain a better understanding of the effect of the tasks on the workers. These assessments made use of an expert-based computer system known as **liftRISK**.

*In situ* testing involved an analysis of the workers' task, a measure of peak and average working heart rates as well as a measure of the workers' perceptual responses to the demands of their tasks. Testing in the laboratory included cardiovascular measures of reference, working and recovery heart rates as well as resting blood pressure; plus isokinetic strength measures of the right arm (concentric grip strength) and trunk muscles (extensors and flexors) using an isokinetic dynamometer. The subjects' perception of their degree of exertion during the trunk strength testing was also measured. During the pre-conditioning laboratory testing a medical history; personal details of age, occupation (in present and previous employment), period of employment (present and previous); and morphological measures of stature and mass were also obtained.

## **LIMITATIONS**

The study involved the use of workers from three very different industries. Consequently, although it would have been optimal to have the subjects involved in the work-hardening programme three times a week for a period of 45 minutes at a time, in an attempt to

standardize the subjects' involvement, it was only possible to run the programme twice a week for a period of 30 minutes during the workers lunch break. This was because workers at the bottling company were only able to participate in the programme twice a week due to the travelling nature of their job and workers at the wholesale warehouse only had a half hour period available during their working day in which to participate in the programme.

The fact that the work-hardening programme was administered during the winter months also presented a problem. Adherence to the programme as a result of vacations (winter is a quiet period for these three industries and a number of workers therefore took their vacation time) or as a result of colds and influenza was thus difficult to control.

Finally, a factor that affected only the participation of some of the workers at the bottling company was that although they finished work at midday on Monday and Fridays, due to the travelling nature of their work they found it difficult to always be back at the warehouse in time for the work-hardening programme. For this reason the bottling industry experienced a large dropout rate from the work-hardening programme which may not have occurred had the workers returned to the warehouse in time.

## CHAPTER TWO

### REVIEW OF RELATED LITERATURE

#### INTRODUCTION

Over the course of the century most advanced countries have experienced a marked decline in mortality from infectious diseases largely as a result of improved environmental conditions and medical treatment. A similar decline in mortalities from injuries has however not occurred and unfortunately a significant percentage of these injuries, ranging from minor to fatal, occur within the work environment (Nordin, 1987; Smith, 1987). Conversely, in a great majority of the developing countries disease is still prevalent, and the result is that the magnitude of occupational diseases and injuries has not been fully appreciated (Asogwa, 1987).

Due to the extensive global problem of occupational injuries, manual materials handling tasks and their associated problems have been an unceasing research topic in ergonomics for the past few decades (Genaidy *et al.*, 1990; Kim and Chung, 1995). According to these and other authors (Ayoub and Mital, 1989; Kuorinka, 1995), even in highly advanced societies manual materials handling tasks are inherent within industry and manual work is still performed by large sections of the community despite the sophistication of modern technology. In fact, Kuorinka and Forcier (1994) maintain that musculoskeletal problems have risen in spite of mechanization and automation and Kuorinka *et al.* (1994) predict that manual handling within the developed countries may even increase in the future as a result of the need for flexibility in operations and information handling that only a human operator

can provide. In addition, Kuorinka *et al.* (1994) point out that the introduction of automation into developing countries does not naturally ensure a reduction in work-related injuries.

Indeed, every year *first world* industries are burdened with an enormous loss of time and resources as a result of occupational injuries. The literature is replete with statistics concerning the magnitude and cost of the problem. Musculoskeletal impairments are considered the most common cause of occupational injuries and loss of work, and rank first amongst the disease groups in terms of frequency and effect in the developed countries (NIOSH, 1982; Lechner *et al.*, 1994). Hochanadel and Conrad (1993), Lechner *et al.* (1994) and Greenberg and Bello (1996) report that in the United States billions of dollars are spent each year on health care services and disabling payments. The problem can only be presumed to be much worse in developing countries like South Africa where records are not as readily available and where manual labour is performed by the majority of workers. For this reason Nordin (1987) alleges that while it has been reported in various *third world* countries that an estimated 10 million workplace injuries and over 50 000 fatalities occur annually, the lack of valid and reliable statistics means that realistic figures are believed to be much higher.

The result is that musculoskeletal injuries in the workplace, both in developed and developing countries, have reached epidemic proportions (Pope, 1987; Nachemson, 1992). The reduction of occupational disorders and associated occupational disability worldwide thus represents a major challenge within the field of ergonomics. This would seem to be particularly true in the labour-intensive industrial environment of South Africa where manual labour, involving physically demanding tasks, is a dominant factor. Indeed in 1994, at a

national South African Ergonomics conference held in Grahamstown, Von Tonder provided the following South African 1988 statistics; a total of 1 762 workers are killed per year (the equivalent of 7 workers per work day) as a result of workplace accidents, whilst 245 577 workers suffer from musculoskeletal injuries in a year. These injuries and mortalities together result in 22 million working days being lost per year within South Africa. It would therefore appear essential for industrialists in South Africa to have information about the capacities for physical effort that characterise the indigenous populations. With such information, work standards can be set in accordance with the physical work capacities of the workers.

### **MUSCULOSKELETAL INJURIES IN PERSPECTIVE**

Whereas in the past, rest was the most common treatment for injuries, today's approach stresses physical rehabilitation and work-hardening. According to Lanes *et al.* (1995) and Greenberg and Bello (1996) the major goals of this active and functional restoration are to correct the deconditioning in the worker with musculoskeletal injuries, to achieve maximal functional improvement and to facilitate the individual's return to work. Although these work-hardening programmes have proliferated in the United States (Brady *et al.*, 1994; Greenberg and Bello, 1996) and are reported to be successful in returning the previously injured worker to the workplace even at an improved level of functioning (Robert *et al.*, 1995), not enough significance has been placed on primary health care in which the emphasis is on prevention rather than rehabilitation.

In South Africa this functional approach does not appear to have been investigated at either a preventative or a rehabilitative level. As local orthopaedic Mackenzie (1992) proposed, a far greater emphasis will have to be placed on primary health care and preventative medicine within South Africa than has been the case in the past in order to reduce the incidence and socioeconomic cost of musculoskeletal injuries. Now is the time for effective strategies in both the prevention and rehabilitation of occupational injuries: the key word should be *control* not cure.

As Smith (1987) points out, occupational injuries are not “accidents or random events” but are “predictable entities” with known risk factors like other diseases. Occupational injuries are therefore not only treatable but also preventable. Indeed, it has been recognized that workers in certain occupations, specifically those who perform strenuous manual materials handling activities, are at a greater risk of being injured. By recognizing the *disease* (occupational musculoskeletal disorders) and the known *risk* factors, and by taking responsibility for the prevention and treatment of these disorders, one can, according to Smith (1987), hope to reduce the burden of occupational injuries on society.

King (1995) claims that first world corporations and unions are beginning to realize the importance of the prevention and early intervention of work-related injuries. As Matheson *et al.* (1995) rationalise, this is as a result of the recent inconceivable increases in the cost of providing care that is effective in returning injured workers to the workplace. According to King (1995), ergonomics is therefore being viewed as a key element in improving safety, health and productivity within developed industries and is being looked to in order to provide a model of health care that emphasises prevention as well as the return to work of the

previously injured worker. Unfortunately ergonomics in most developing countries is still very much in its infancy. In South Africa, a country of about 40 million people, the ergonomics society has been in establishment for 12 years and has roughly 70 society members with only seven registered ergonomists.

As Haddon and Baker (1981) explain, the principle behind preventing the occurrence of injuries is basic: keep potentially harmful agents from reaching people in amounts or rates that exceed injury thresholds. Already in 1977, Tuxworth and Shahnavaaz recognized that what was needed was a determination of "acceptable work levels" for the available manpower. These acceptable work levels of Tuxworth and Shahnavaaz (1977) can be compared with Genaidy's (1992) *ergonomic stress index*. The emphasis of both is on reducing the job requirements in order to reduce the onset of musculoskeletal injuries. Although Tuxworth and Shahnavaaz (1977) and Genaidy (1992) place the emphasis on reducing the job requirements, it is possible that by improving the workers' physical work capacity one may further reduce the ergonomic stress index. These authors do however stress that wherever the acceptability lies it must be related to the *physical work capacity* of the particular workforce. This is particularly significant in South Africa where studies have shown that work-study standards based on Europeans are wholly unrealistic in the employment of the indigenous population (Wyndham, 1975).

As Genaidy *et al.* (1992) and Waters *et al.* (1993) recognise it is the physical demands of many industrial operations which are responsible for the multitude of musculoskeletal disorders reported in industry. Manual materials handling, which involves the act of lifting, lowering, carrying, pushing, pulling and holding, is one of the most important etiologic

factors in terms of occupational musculoskeletal disorders. An analysis of US accident statistics over the years 1982-1987 showed that 60% of over-exertion incidents involved manual lifting, 18% involved the pushing, pulling, handling or throwing of objects and 22% involved strenuous movements (Tang, 1987). In 1990, Genaidy and his associates acknowledged that the performance of manual tasks exerts biomechanical, physiological as well as psychological strain on the body and thus exposes the worker to a variety of physical stresses resulting in musculoskeletal injuries, particularly low-back problems. In the last 15 years many authors have reported that the manual handling of heavy objects is considered to be a major cause of high disability rates, specifically low-back pain and low-back impairment (Garg *et al.*, 1980; Liles *et al.*, 1984; Garg and Badger, 1986; Boocock *et al.*, 1988; Bush-Joseph *et al.*, 1988; Genaidy *et al.*, 1990; Ayoub, 1992; Van Dieën *et al.*, 1993; Genaidy *et al.*, 1994 Marras *et al.*, 1995).

The use of work-hardening programmes as a prophylactic endeavour within South African industry to improve the physical work capacity of workers, through physical conditioning and maximal functional improvement, may thus be seen as a feasible approach to maintaining acceptable work levels without necessarily reducing job requirements. In such a manner the ergonomic stress index may be reduced and idealistically, so too can the onset of occupational musculoskeletal injuries, specifically occupational low-back pain.

## **OCCUPATIONAL LOW-BACK PAIN**

According to Frymoyer (1992), disability from low-back pain is distinctively a twentieth

century phenomenon, for before the latter part of the nineteenth century back pain was viewed as a rheumatic condition with medical care rarely sought for its treatment. As a result, worker's compensation and social entitlement programmes were not available. Evidently it was as a result of Mixter and Barr's (1934) discovery of the lumbar disc as a source of clinical symptoms and signs, combined with the growing awareness of worker's compensation, which promoted a new belief that low-back pain often resulted from occupational injury and was therefore compensable. Today mechanical and psychosocial factors have been implicated, and low-back pain resulting from work demands is recognized as a major health concern of industries worldwide (Marras *et al.*, 1995).

Indeed, according to Feldstein *et al.* (1993) and Johns *et al.* (1994), low-back injuries are the largest subset of musculoskeletal injuries in the workplace although Ayoub and Mital (1989) and Hildebrandt (1995) argue that, in general, the percentage of low-back pain which is occupation-related is difficult to determine.

Ranney *et al.* (1995) explain that the establishment of work-related low-back pain requires both the quantification of exposures involved in work and a determination of health outcomes. With respect to this relationship, Klein *et al.* (1984), Harber *et al.* (1985) and Feldstein *et al.* (1993) report that nurses, aides and orderlies appear to be particularly vulnerable to low-back pain by virtue of their occupation as, according to these authors, nurses experience more back injuries than most occupational groups. This fact is emphasized by Larese and Fiorito (1994) who claim that the percentage of back injuries amongst hospital nursing staff is more than that found amongst workers in heavy industry and is over twice that of administrative employees.

According to Klein *et al.* (1984) construction and mine workers also appear to be plagued by back injuries. Construction workers in the United States are rated first for number of claims according to claims per 100 workers, whilst mine workers are ranked second. *Table I* describes the distribution of compensation claims for back sprains/strains by industry employment. Estimated employment in each industry is included as are the claims per 100 employees. It is of interest to note that nursing is not included in this table.

**Table I:** 1979 ratios (claims per 100 workers) of compensation claims for back strains/sprains by industry (from Klein *et al.*, 1984).

| Industry                   | No. of claims  | Estimated employment in (1000s) | Claims per 100 employees |
|----------------------------|----------------|---------------------------------|--------------------------|
| Construction               | 31 028         | 1964.2                          | 1.6                      |
| Mining                     | 4 946          | 319.5                           | 1.5                      |
| Transportation             | 25 338         | 2166.7                          | 1.2                      |
| Manufacturing              | 92 556         | 8871.4                          | 1.0                      |
| Agriculture                | 6 077          | 677.0                           | 0.9                      |
| Services                   | 53 313         | 7371.5                          | 0.7                      |
| Wholesale/retail trade     | 56 745         | 8956.3                          | 0.6                      |
| Government (state & local) | 14 463         | 5859.9                          | 0.2                      |
| Finance                    | 4 032          | 2063.6                          | 0.2                      |
| <b>Total</b>               | <b>285 468</b> | <b>38 250.1</b>                 | <b>0.7</b>               |

Hildebrandt (1995) however emphasizes that despite the magnitude of the problem of low-back pain, there is still limited knowledge on the prevalence rates of back pain in specific trades and professions. Although many studies are available on back pain in specific worker populations, the data from these studies are often not comparable due to a large variation in the applied methods.

This makes it difficult to obtain a valid overall picture of differences in the prevalence rate of back pain in different trades and professions. This problem is particularly valid in South Africa and other developing countries where there are very limited sources to provide representative, comprehensive and comparable data on injuries in different trades and professions.

#### THE FREQUENCY AND EFFECT OF OCCUPATIONAL LOW-BACK PAIN

According to Chaffin and Park (1973), in 1972 Snook and Ciriello noted that the incidence rate of occupational low-back pain appeared to be increasing faster than the rate of other types of compensable injuries. Today this problem is still very evident as consistent research has shown that low-back pain is the most common cause of disability and a primary source of absenteeism and compensation claims (Vällfors, 1985; Garg and Badger, 1986; Pope, 1987; Ayoub and Mital, 1989; Bigos *et al.*, 1992; Frymoyer, 1992; Nachemson, 1992; Pope and Hansson, 1992; Krause and Ragland, 1994; Cram and Vinitzky, 1995; Greenberg and Bello, 1996) with the number of workers reporting injury from low-back problems continuously increasing (Lanes *et al.*, 1995; Ryan *et al.*, 1995). Although exact estimates of the severity of the problem are difficult to acquire, several studies have identified that back injuries account for between 20% - 40% of all compensable work injuries (Pope *et al.*, 1991; Johns *et al.*, 1994; Burton *et al.*, 1995; Marras *et al.*, 1995) and whilst Lanes *et al.* (1995) estimate that at least 28% of the industrial population will be temporarily disabled by back pain, Krause and Ragland (1994) report that about 60% of all employees experience some low-back pain at some time in their employment careers.

Consequently, Frymoyer (1992) and Tarasuk and Eakin (1994) emphasize that the medical, personal, social and economic costs resulting from occupational low-back disability are enormous. Marras *et al.* (1995) and Ryan *et al.* (1995) maintain that low-back pain is considered the single most costly musculoskeletal injury found in industry. Recent figures illustrate that in the USA in 1990 direct and indirect costs due to back disability amounted to 50 billion dollars (Frymoyer, 1992; Vlok, 1995) whilst Pope and Hansson (1992) claim that one million back injuries are reported per year in the United States accounting for 100 million worker days lost each year. As Burton *et al.* (1995) and Kim and Chung (1995) explain, not only do industries pay workmen's compensation, lawsuit awards and medical expenses, but they also lose billions through the reduced productive working capacity and lowered morale of the injured worker. *Table II* compares the international yearly incidence of disabling low-back pain in the industrially developed countries. Unfortunately, as previously mentioned, these types of statistics are not readily available in industrially developing countries.

Research has identified that low-back pain tends to strike younger people and that under the age of 45 years the impairment of the back is the most frequent chronic condition limiting activity (Chaffin, 1974; Parnianpour *et al.*, 1987; Pope and Hansson, 1992; Ryan *et al.*, 1995; Vlok 1995). There is growing evidence that low-back problems are not only an ailment of men, of blue collar workers or of older persons, as was commonly thought. Rowe (1971) noted that the onset of back symptoms often occurs in persons between 20 and 35 years old whilst Vällfors (1985) and Feuerstein (1991) report that the first episode of back pain usually occurs before the age of 30 years with absenteeism, as a result of back complaints, escalating with increasing age. In the age group 54 to 64 years, lower back pain

**Table II:** International comparisons of yearly incidence of disabling low-back pain (from Vlok, 1995).

| Country       | Population (millions) | Back diagnoses (% of workforce sick listed per year) | Average days back-related absence per patient per year |
|---------------|-----------------------|--|--|
| USA           | 240                   | 2  | 9  |
| Canada        | 23                    | 2  | 20   |
| Great Britain | 55                    | 2  | 30   |
| West Germany  | 61                    | 4  | 10   |
| Netherlands   | 14                    | 4  | 25   |
| Sweden: -     |                       |  |  |
| - 1980        | 8                     | 3  | 25   |
| - 1983        | 8                     | 5  | 30   |
| - 1987        | 8.5                   | 8  | 40   |

has been identified as the third leading cause of industrial disability (Vlok, 1995). According to Nachemson (1976) women are afflicted as often as men, and white collar workers as often as blue collar workers. Vällfors (1985) and Lindström *et al.* (1994) however, claim that more recent studies have indicated an increased absenteeism amongst manual workers as compared to white collar workers, and Vällfors (1985) points out that individuals with a physically demanding job suffer from back conditions at an earlier age compared to individuals with a physically less demanding job. According to Bigos *et al.* (1986a) and Cohen *et al.* (1994) the incidence of occupational lower back pain is highest during the most productive years of life (ages 25 -60 years).

Despite the fact that numerous epidemiologic studies have been done worldwide, the incidence of low-back pain within South Africa, a country where manual tasks demanding

varying degrees of muscular activity are especially prevalent, is not yet well known. According to Vlok (1995), the Workers Compensation Act rates back pain in South Africa as the most common cause of disability under the age of 45 years, although industrialists seem to think that this condition is reportedly often cited as an excuse for absenteeism.

Studies of the natural history of back pain suggest that for most conditions the prognosis is favourable, and the risk of progression small. According to Tarasuk and Eakin (1994), the majority of workers with back problems are absent from work for less than one month and only 5 - 10% go on to long term disability. However, as Frymoyer (1992), Krause and Ragland (1994) and Ryan *et al.* (1995) stress, this 5 - 10% accounts for more than 75% of the costs associated with the low-back pain. In addition, Burton *et al.* (1995) hypothesize that the prognosis for low-back pain is not as good as is generally believed as the symptoms can follow a fluctuating course which may lead to the erroneous assumption that the patient has recovered if assessed too early.

Indeed, studies have shown that low-back pain tends to be recurrent in nature, although the individual may be pain free between episodes. Rowe (1971) identified that episodes of low-back pain can occur every three months to three years and that 83% of those individuals with low-back pain have recurrent attacks, whilst Nachemson (1971) believes that the frequency of repeated episodes peaks between the ages of 40 to 50 years. According to Burton *et al.* (1995) low-back pain has a propensity to recur particularly in the first year whilst for some the problem seems to persist even in the absence of a demonstrable pathology.

Factors specifically related to the persistence of symptoms and recurrences of low-back pain

were investigated in a study done by Troup *et al.* (1981). These authors found that amongst the factors of importance were: age, back injuries caused by accidents (falls), a longer sickness absence for the current attack, a shorter interval since the last low-back episode, the previous use of medical services, sciatica during the current low-back pain episode and/or sciatica during previous back pain attacks. According to these same authors the working environment and conditions have also been shown to influence the frequency and duration of absenteeism and Vällfors (1985) found that absenteeism increased amongst individuals under psychological and social pressure.

These facts do not, however, reflect the potential socio-economic effects of low-back pain. According to several authors individuals absent from work for prolonged periods of time (4/6 months and more) are, in the absence of innovative programmes, unlikely to ever fully return to productive employment (McGill, 1968; Snook, 1982; Machaver, 1987; Frymoyer, 1992; Hochanadel and Conrad, 1993).

Indeed, a qualitative study conducted by Tarasuk and Eakin (1994) reveals that workers often perceive their back problems to be lifelong problems. In addition, many believe that their back injuries have permanently heightened their vulnerability to reinjury and chronic disability. According to Tarasuk and Eakin (1994), accommodating this sense of physical vulnerability requires a redefinition of one's self and one's future. Evidently, for some workers the perceived threat of future back problems is in itself disabling and appears to discourage a return to normal social roles as well as exerting a strong influence on the worker's attitude towards returning to work. For some individuals, the perceived physical limitations associated with their back problems are extensive. Many are concerned, as well

as reluctant, about resuming pre-injury work activities, especially amongst those individuals who attribute their back problems to the routine physical demands of the job. The fact that having a work-related back injury prompts some individuals to search for new jobs, particularly at a time of high unemployment worldwide, highlights the dramatic impact that a back-problem has on an individual's life.

Consequently, as a result of the statistics provided, the fact that manual materials handling, specifically lifting, is such an integral part of labour-intensive South African industry together with the fact that the potential social and economic benefits of reducing the magnitude of industrial low-back pain emphasize the importance of the need for the development of effective methods of prevention, plus early intervention programmes within South Africa, in order to ameliorate the appalling effects of musculoskeletal injuries like low-back pain.

Unfortunately, due to the episodic nature of the symptoms of low-back pain, causation is very difficult to establish and as Chaffin (1974) stressed, referring to low-back pain as an "injury" is not doing justice to the complexity of the problem.

## **THE ETIOLOGY OF OCCUPATIONAL LOW-BACK PAIN**

Although back pain is one of modern man's most common ailments, little medical agreement as to cause or cure has been reached. Already in 1969 Rowe identified that investigation had been hampered by the multitude of interlocking causal factors and the relative lack of objective diagnostic findings. As such, efforts to discover a single etiological key to the low-

back problem have spanned generations of "fad" diagnoses.

"The day of the sacro-iliac sprain was superseded by the era of lumbo-sacral strain and this, in turn, by the currently fashionable slipped disc (sic). Members of various speciality groups concerned with low-back disability further confuse the picture as they report experience with patients who fall into their respective fields of competence. Psychiatrists (sic) regard weak trunk muscles as the cause of most backache while psychiatrists find situational problems at the root of back disability. Neurosurgeons describe ruptured discs as the etiological key and orthopaedists find mechanical defects." Rowe (1969:p161)

Twenty years later, Barron and Feuerstein (1994) affirm that despite the availability of sophisticated diagnostic tests, the precise pathophysiologic mechanisms of low-back pain cannot be determined in the majority of cases. The epidemiology of occupational back pain, and musculoskeletal injuries in general, are areas characterized by several definitional, measurement, conceptual and methodological problems making it difficult to establish the exact origin and scope of the risk factors involved, let alone the causal factors (Kemper *et al.*, 1990; Feuerstein, 1991). The problems that Rowe spoke of in 1969 are therefore still prevalent and low-back pain is typically a non-specific diagnosis. As a result, it is currently unclear as to what causes low-back pain in a large proportion of injured workers. Despite this, Pope *et al.* (1991), report that in view of the variety of socio-economic conditions among countries, the number of similarities in the epidemiology of low-back pain is surprising.

#### WORK-RELATED RISK FACTORS

Bigos *et al.* (1986a) identify that one of the major thrusts of investigation into activities and events associated with the onset of low-back pain has been to identify jobs associated with

a high incidence of back injury. According to these authors, epidemiological studies indicate very little difference in the incidence of low-back pain in workers performing a variety of jobs whilst information based on sick leave records and insurance data identifies jobs involving certain tasks as the cause of industrial back injury.

This latter view would seem to be shared by many researchers in the field as numerous studies on low-back pain have shown clear relationships between low-back injuries and tasks involving lifting, pushing and pulling, bending, twisting and maintaining certain positions; in other words virtually any physically demanding work. Indeed manual materials handling activities have been verified as significantly increasing the stress on the spine (Chaffin and Park, 1973; Andersson, 1981; Klein *et al.*, 1984; Bush-Joseph *et al.*, 1988; Ayoub and Mital, 1989; Magnusson *et al.*, 1990; Punnett *et al.*, 1991; Burdorf *et al.*, 1993; Waters *et al.*, 1993; Genaidy *et al.*, 1994; Lindström *et al.*, 1994; Marras *et al.*, 1995). However, several of these authors also recognise that less physically stressful, but boring and repetitive jobs such as assembly-line work increases a worker's risk for low-back pain. These authors thus acknowledge the psychological aspect of low-back injury. In addition, in many work environments workers are exposed to vibration from equipment such as pneumatic drills, rivetting hammers, large turbines or heavy equipment such as tractors, loaders and forklifts. Several reports have related vibration exposure to low-back pain and various spinal disorders (Frymoyer *et al.*, 1980; Village *et al.*, 1989; Bongers *et al.*, 1990).

The controversy surrounding jobs associated with a high incidence of back pain has also been investigated by Vällfors (1985). According to this author, investigation done up until the 1980's revealed that the incidence of low-back pain was no greater amongst individuals

performing heavy physical work versus individuals performing light work. The duration of absenteeism was, however, found to be longer amongst individuals who performed heavy manual labour as it was more difficult for these workers to return to a job where they were expected to perform heavy lifts when the symptoms of back pain were still present. Vällfors (1985) added that studies done around the same time (Magora, 1972 and 1973) indicated an increased frequency of low-back pain amongst individuals involved in sedentary jobs. Magora (1972) reported that people who sat for prolonged periods of time experienced more back pain than those not confined to their seats. Moreover, according to Nachemson (1981), the pressure induced in the back by unsupported sitting alone exceeds that of standing postures by 40%. More recently, Burdorf *et al.* (1993) added that although conclusive epidemiological evidence is lacking, sedentary labour is seen as a risk factor for low-back pain as a result of increased disc pressure associated with the sustained static loading of the lumbar spine.

These studies illustrate that back pain affects individuals with both physically demanding jobs and those with lighter work. As Machaver (1987) clarifies, the injury most common to all employees is low-back injury. Although, according to Chaffin (1974), and currently Genaidy *et al.* (1994), manual materials handling activities are considered the most hazardous acts in industry, Waters *et al.* (1993), Barron and Feuerstein (1994) and Boocock *et al.* (1994) admit that activities and events associated with an increased risk of low-back pain include most work-related components: from heavy physical work to prolonged sitting and standing, vibration and accidents. In addition, evidence exists that work-related psychological stress and lifestyle factors may also increase the risk of low-back pain and the subsequent risk of prolonged impairment (Vällfors, 1985; Bigos *et al.*, 1986b) suggesting that back pain truly

has a multifactorial etiology. As Snook *et al.* (1970) and Lechner *et al.* (1994) reason, of relevance is that any physical demand<sup>#</sup> that exceeds a worker's physical capabilities will lead to some form of musculoskeletal injury resulting in a disability. Likewise, Nachemson stated that:

“the common denominator (in the etiology of low-back pain) is that trouble arises from the areas of the spine subjected to the heaviest mechanical stress in its widest sense” Nachemson (1976: p61).

#### **A BIOMECHANICAL BASIS FOR THE ETIOLOGY OF LOW-BACK PAIN**

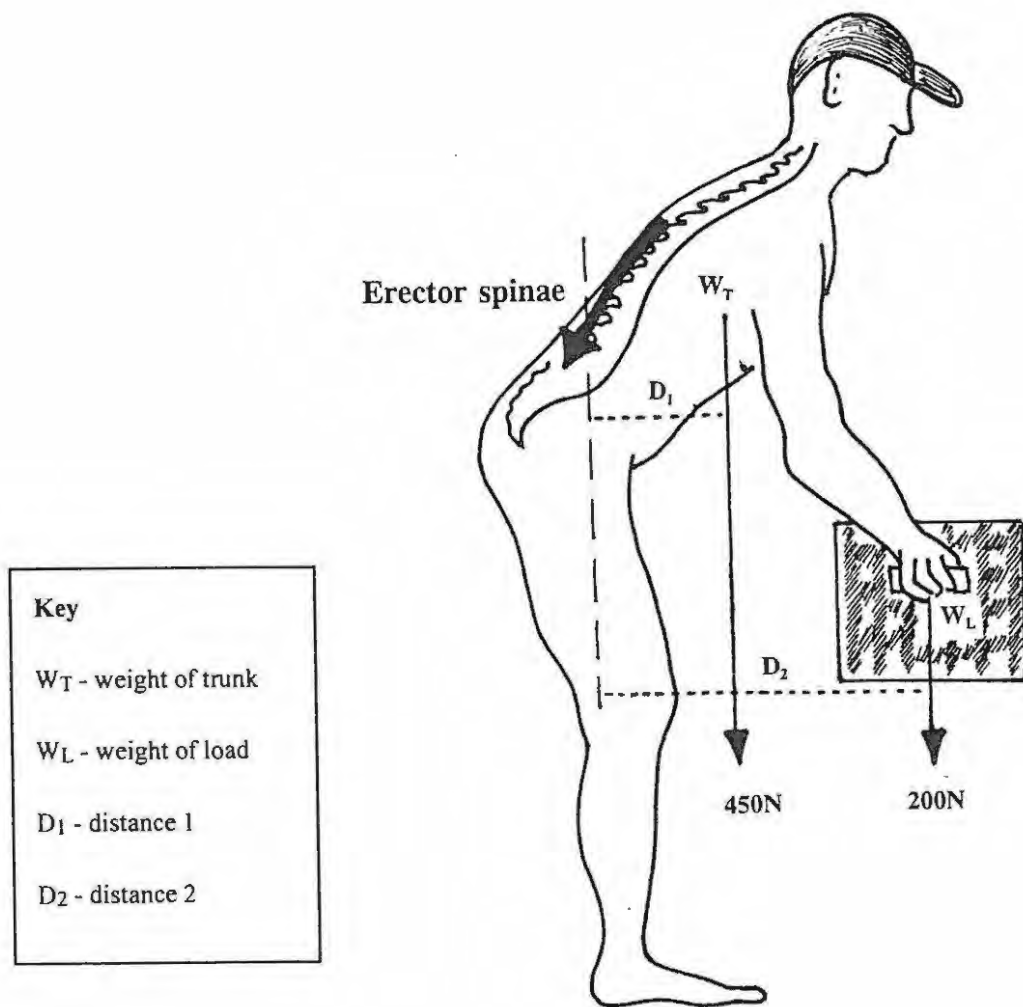
Another major thrust of investigation into the etiology of lower back problems is the biomechanical analysis of manual material handling tasks. According to Wheeler *et al.* (1994), such an analysis is essential in developing guidelines for safe working environments and it is from such analyses that a biomechanical basis for the etiology of low-back pain has evolved. Barker and Atha (1994) explain that biomechanical models estimate the stress on the spine by analyzing the forces and torques (force x lever arm of force) acting on the body. In turn, Barron and Feuerstein (1994) maintain that these occupational biomechanical models are used in efforts directed at the prevention of low-back pain by providing a basis for administrative controls and/or engineering modifications in the workplace. According to these authors, such models suggest that low-back injuries occurs when compressive, shearing and torsional forces acting on the lumbar spine exceed the underlying capacity of the worker.

# The physical demands of the workplace may be defined as the physical aspects of successfully performing job requirements and include work postures (positions), body movements, forces applied to the worker, repetition of the work tasks, and other ergonomic stressors and hazards.

Traditionally however, most biomechanical assessments of work situations have been limited to static evaluations of the trunk and have focused primarily on the spinal compression associated with lifting. An obvious criticism, state Barker and Atha (1994), is that this leads to an underestimation of the forces and moments generated and, as Marras *et al.* (1995) report, studies have shown that lateral shear forces render the motion segment of the spine far more vulnerable to injury than compressive loading.

Li (1995) emphasizes that the body is constructed in three dimensions and that any simple body movement needs an integrated effort of various muscles. These muscles have to co-contract concentrically and eccentrically in combination and maintain whole body balance during a dynamic lift. Marras *et al.* (1995) explain that the dynamic trunk motion components of a lift are associated with greater spine loading as the moment of inertia and angular acceleration have to be added to each force in the clockwise direction thereby increasing the moments in this direction. In addition, shear and torsional loadings become more prevalent when the speed of trunk motion increases, and as Li (1995) recognises, the natural lifting speeds of workers performing lifts may be as fast as  $150^{\circ}.\text{sec}^{-1}$ . Likewise, Barron and Feuerstein (1994) report that the asymmetric loading of the lumbar spine is another factor associated with an increased risk of injury. Indeed, according to Nachemson (1992) patients complain that different positions and movements cause increased pain. It is however only recently that there has been an attempt to quantify these three dimensional trunk motion components in the workplace.

Because problems generally arise at the L<sub>5</sub>/S<sub>1</sub> segment, this is the joint that has been the most often studied. *Figure 1* illustrates an individual lifting a load and indicates the forces and torques involved.



**Figure 1:** The forces and torques involved in lifting.

Traditional 2-dimensional biomechanical models predict that due to the large bending moment at the  $L_5/S_1$  region of the spine during a lift, the paralumbar muscle must generate high forces in order to counteract the torque. These high forces are responsible for a significant portion of the resultant compressive forces acting on the  $L_5/S_1$  disc. These models are however simple and ignore the fact that lifting is a dynamic motion (Barron and Feuerstein,

1994).

Based on these biomechanical considerations, physically conditioned employees in jobs requiring considerable physical effort are assumed to be less liable to develop back disorders than the less physically conditioned due to the increase in the strength of their *erector spinae* i.e. in the “effort” force. Although the evidence for this is contradictory (Battie *et al.*, 1989a; 1989b; Leino *et al.*, 1994), the rationale of work-hardening programmes is partly based on this assumption.

#### A BIOLOGICAL BASIS FOR THE ETIOLOGY OF LOW-BACK PAIN

The intervertebral disc is an interesting biologic structure which, according to Nachemson (1976) slowly becomes more inflexible with age, loses its resilience and shrinks due to gradual dehydration. The disc therefore becomes gradually more brittle as well as more likely to rupture as an individual ages or as Sperryn (1983) emphasises, with continual heavy loading of the spine.

The nucleus pulposus of the disc consists of a three-dimensional network of sparse collagen fibrils enmeshed in a mucoprotein gel which contains various glycosaminoglycons. Nachemson (1976) explains that these bind water and as people get older so their glycosaminoglycon numbers diminish and therefore so does the water content of the nucleus. Since some of these glycosaminoglycons are acid it was once thought that these could cause pain. Subsequently however, it was demonstrated that this was not all due to the glycosaminoglycon concentration, but rather to an increased amount of lactate. Lactate in

large amounts is produced when cells metabolize under anaerobic conditions and the disc is the largest avascular structure in the body, devoid of directly penetrating vessels from age 15-20 years on.

According to Nachemson (1976) this fact prompted a new line of biologic investigations. It was found that direct vascular contacts between the marrow spaces of the vertebral body and the hyaline cartilage of the end-plates were of universal importance and that these contacts were significantly fewer in discs that showed advanced degenerative changes. It was also found that the central part of the disc and especially the boundary zone between the nucleus pulposus and annulus fibrosus were exposed to nutritional deficiency.

In addition, it was possible to demonstrate using a dog that glycosaminoglycon turnover is very slow, around 500 days, as measured by the turnover time for sulphate ions. Unfortunately, according to Nachemson (1976), the collagen turnover is even slower which explains why ruptured discs take a long time, if ever, to heal.

In an update of knowledge on low-back pain, Nachemson (1992) added that no evidence had been found of free naked nerve endings inside the vertebral disc, but that there has been an abundance of new studies demonstrating their existence in the outer part of the annulus fibrosis, in the dorsal longitudinal ligament, and in the facet joint capsules.

Combining these biologic findings with a knowledge of mechanics allows the pattern of degeneration in the disc and the pattern of degeneration which results in low-back pain to emerge, since mechanically finite element analyses of the disc using available data from

previous mechanical tests points to the area between the nucleus and the annulus as an especially strained one, whilst again this is the same part of the disc where the special metabolic requirements are rather poorly met (Nachemson, 1992).

In addition, Barron and Feuerstein (1994) reveal that cadaver studies illustrate that axial loads near the action limit of 3400 Newtons produce microfractures in the cartilaginous end-plates and posterior annular fibres of the intervertebral disc. According to these authors, it is hypothesized that this microtrauma contributes to the etiology of degenerative disc disease and reduces the threshold for low-back injury.

However, even with this better biological understanding of pain, Nachemson (1992) maintains that the pathomechanism of lower back pain is still unknown, and unfortunately for the majority of patients physicians still do not know what specific structures in and around the motion segment are the source of low-back pain.

#### **PSYCHOLOGICAL RISK FACTORS**

For many years it was thought that mechanical factors were of the essence in the development of low-back pain and that the upright posture of *Homo sapiens* was to blame. It has since been established that low-back pain depends not only on physical factors, but also on psychological factors and that psychosocial factors play an important role as low-back pain often occurs in industrial workers without there being any obvious impairment or malfunction. According to Nachemson (1992) it is therefore imperative that psychologic signs not be interpreted as physical problems. He warns that orthopaedic surgeons must

recognise this fact, for although previous emphasis on the clinical characteristics of low-back pain has led to ever increasing refinements in clinical diagnostics, rarely are diagnoses completely scientifically valid and they allow for the relative neglect of the psychosocial concomitants of back pain. It is for this reason, according to Burton *et al.* (1995), that there has been no subsequent reduction in the problem of low-back pain.

Although physical work factors, such as heavy lifting are consistently found to increase the risk for back pain, in the last decade an increasing amount of studies have revealed the importance of psychosocial factors in patients with low-back pain. Both Frymoyer (1992) and Nachemson (1992) claim that it has been demonstrated that the behaviour component of a patient's disability can be considered more important than the underlying presumed physical trouble.

“Clinical studies with good controls and non-biased follow-up examinations have illustrated that psychological factors need to be addressed more thoroughly than hypothetical physical problems or biomechanical factors.”  
Nachemson (1992:p16).

In addition, during the last decade research into basic neurophysiological pain mechanisms has intensified. Nachemson (1992) explains that it is now known how various centres in the brain stem can be modulated by various psychological influences and can alter the production of pain mediating chemical substances such as enkephalines and serotonin. This means that it may now be possible to explain why a person interprets any ailment or irritation as more painful whilst tired, discontented or depressed.

The question however arises, are psychological factors secondary to the experience of

back pain or are they operative from its inception. According to Klenerman *et al.* (1995), during the last 50 years explanatory models of back pain adopted by the medical profession have swung between the mechanical/postural and the behavioural/psychological. Whilst some authors have suggested that 90% of symptoms can be explained on the basis of disc pathology, others have reported increased levels of psychological distress such as depression and anxiety amongst back pain sufferers; reports that are consistent with a multifactorial etiology for low-back pain in which psychological factors are seen to play a significant role.

A recent observation made at a Texas rehabilitation clinic motivated Blair and associates (1994) to investigate the relationship between emotionally traumatic experiences and chronic back pain. Patients at the Texas clinic, suffering with chronic back pain, were encouraged to attend a workshop in order to be motivated into active responsibility for their rehabilitation. It was during the first sessions of the workshop that it was noted that these chronic back pain patients were disclosing an unusual amount of pre-injury emotional trauma, experiences considered out of the range of usual life experiences. This observation led Blair *et al.* (1994) to study the workshop data. In their review of the literature, these authors found what seemed to be a relationship between psychological factors and low back pain.

According to Blair *et al.* (1994) studies have reported unsuccessful outcomes in up to 85% of patients who have had three or more of five serious childhood psychological traumas (physical abuse, sexual abuse, alcohol and drug abuse, abandonment, and emotional abuse) and have shown that before the onset of back pain there is a significant excess of adverse life events in patients with a definite back pain of uncertain cause when compared with those patients with a specific diagnosis. Nachemson in 1976 already warned that back surgery

should be avoided in patients with obvious psychological disturbances. In Frymoyer's (1992) review of the literature, he reports that studies indicate that individuals disabled with low-back pain are characterized by alterations in the hysteria, hypochondriasis and depression scales (often termed the "inverted 'V' profile") when evaluated using the Minnesota Multiphasic Personality Inventory (MMPI).

According to Kinney *et al.* (1993), it has long been recognized that chronic low-back pain patients often exhibit psychopathology which may play a role in the etiology and maintenance of this disability syndrome. In addition, Vällfors (1985) and Bigos *et al.* (1986b) report that evidence exists that work-related psychological stress and lifestyle factors increase the risk of low-back pain as well as the subsequent risk of prolonged impairment, and according to Frymoyer (1992) psychosocial and work environment factors are far more accurate predictors of disability than physical factors.

### **The Effect of The Work Ambience**

A variety of studies have analyzed the work environment and its effect on disability. One of the most instructional investigations is that of Vällfors (1985) in which she identifies the work environment as a major determinant of short-and long-term disability from low-back pain. Job dissatisfaction, noisy or unpleasant work conditions, repetitive and often menial job tasks are identified as independent variables associated with disability. Likewise, Frymoyer (1992) states that the worker's physical condition may be a modest determinant of continuing disability, whereas psychosocial factors, the work environment, and the patient's interaction with that work environment may be critical determinants.

## The Effect of Workers Compensation

In a study conducted by Ambrosius *et al.* (1995), it was found that it took worker's compensation individuals longer, from the time of injury, to receive therapy and that this group also required more therapy than their counterpart, a group of noncompensation members. According to Frymoyer (1992) and Nachemson (1992), there is little question that the payment of compensation has been demonstrated to be more important than biomechanical workloads. In addition, Sanderson (1995) maintains that patients claiming compensation are regarded as more likely to be influenced by psychologic factors, especially when they are no longer employed. Trief and Donelson (1995:p185) however argue that there is general recognition that the Worker's Compensation System "...has evolved into a costly adversarial, stress engendering set of interactions". In comparison to authors such as Frymoyer (1992), Nachemson (1992) and Ambrosius *et al.* (1995), Trief and Donelson analyze the way in which the system is in itself pathogenic. This controversy highlights the need for a move from a focus on the individual to a focus on the system and its interaction with the individual. Trief and Donelson (1995) however, do not dispute that there is a risk of the compensation system being abused especially when the individual is a malingerer or has limited coping skills.

# **THE PRO- AND RE-ACTIVE TREATMENT OF OCCUPATIONAL LOW-BACK PAIN**

## **PROPHYLACTIC METHODS**

Throughout the course of this chapter it has been repeatedly established that occupational low-back injuries are a leading problem in both developed and developing countries, and are responsible for a significant proportion of absenteeism, health care and workmen's compensation costs. Naturally industries worldwide would prefer not to incur the lost time and increased financial costs associated with these injuries. South Africa specifically, with its struggling economy cannot afford the increasing costs associated with absenteeism and occupational injuries like low-back pain.

Within the advanced countries, there has been a growing interest in the prevention of occupational low-back injuries at individual, corporate and governmental levels. According to Karwowski (1993), the past two decades have witnessed increasing efforts in the selection of certain workers and the production of regulations and standards specifically designed to protect workers from occupational hazards and prevent musculoskeletal disorders resulting from manual materials handling.

### **1) Identification of the Individual at Risk**

In the past industries relied on medical resources to reduce the incidence of lower back disability and the resultant costs by attempting to identify individuals at greater risk.

According to Bigos *et al.* (1992), the medical fraternity originally responded by recommending pre-employment screening i.e. if the job to be performed was known to require lifting and moving of materials which could stress the low back, then special consideration was to be given to the health and functional capability of the person's back.

The primary prevention of low-back pain in industry therefore focused on assessing the person's ability to perform physical labour. Rowe (1969) emphasized the need for good pre-employment medical histories and physical examinations due to the fact that low-back pain tends to be a recurrent problem.

The pre-employment physical assessment was most often based on a clinical evaluation of a combination of X-ray findings and physical characteristics of the torso. Evidently it was believed by many practitioners during the 1960's that radiographic findings would be most helpful in predicting a person's ability to tolerate low back stresses (Chaffin and Park, 1973). According to Reimer *et al.* (1994), this belief has not been well justified by empirical evidence. The information obtained from ordinary X-rays is mostly irrelevant, as seen in *Table III* where questionable, as well as relevant indications for low-back pain are listed. In the majority of patients between 30 and 50 years of age, X-ray investigations reveal little that is not seen or at least suspected in a clinical examination (Nachemson, 1976; Valkenburg and Haanen, 1982; Reimer *et al.*, 1994).

## **2) Employee Selection and Placement**

With the implementation of pre-employment screening procedures industries are able to pre-

**Table III:** Radiologic abnormalities in the lumbar spine with significance for low-back pain  
(from Nachemson, 1976).

| Classification | Abnormality   |
|----------------|---|
| Irrelevant     | Single disc narrowing and spondylosis<br>Facet arthrosis, subluxation and tropism<br>Lumbarization, sacralization<br>Intraspongy disc herniation (Schmorl)<br>Spina bifida occulta<br>Accessory ossicles<br>Mild-moderate scoliosis |
| Questionable   | Spondylolysis<br>Retrolisthesis<br>Severe lumbar scoliosis (> 80°)<br>Severe lordosis   |
| Definite       | Spondylolisthesis<br>Lumbar osteochondrosis (Scheuermann)<br>Congenital/traumatic kyphosis<br>Osteoporosis<br>Marked multiple disc narrowing<br>Ankylosing spondylitis  |

select workers physically equipped for the available job. Pre-selection procedures are, however, fraught with limitations. As Rowe (1969) points out, an obvious drawback in using a medical history for employee selection is that it relies on a person's memory and motivations, both of which may be influenced by many other factors. Similarly, the lack of predictive power coupled with the cost and potential radiation hazard of a radiographic examination greatly reduces the utility of lumbo-pelvic X-rays for employee selection and placement.

Several other methods have been developed for employee selection and placement, yet according to Lechner *et al.* (1994) and Cohen *et al.* (1994), to date there is no strong evidence for a screening test that has demonstrated high sensitivity and specificity or that is

established as a good predictor of functional ability. Poulsen and Jorgensen (1971) suggested torso isometric strength testing as a means of predicting a person's ability to safely perform manual materials handling. According to Nachemson (1976), testing of such a method to predict susceptibility to low back pain has not been well documented. It would however, appear to be supported by Rowe's (1969) findings that torso weakness (by abdominal muscle tests - situps) is much more prevalent in those people with low back pain. Tichauer *et al.* (1973) proposed that the change in the curvature of the person's lumbar spine when physically loaded discloses inherent weaknesses in the musculoskeletal system. Dales *et al.* (1987) and Gamberale *et al.* (1987) reported on various other techniques and examinations such as direct measures of spinal loading (intra-discal pressure), which is the least practical to perform on populations; intra-abdominal pressure measures which correlate with spinal stress but have the disadvantage of being invasive and back muscle electromyography readings which are difficult to interpret. Dales *et al.* (1987) themselves hypothesized that a measure of the transient bending moment over the abdomen during a given manual handling task might be related to the load on the spine for that task.

### **3) Quantifying Safety Regulations**

In comparison, Pope and Hansson (1992) point out that risk factors related to the industrial environment are ones over which one can exercise some control. Indeed, efforts have been made to prevent industrial back problems by minimizing physical hazards at the workplace through establishing and enforcing safety and health regulations. This approach involves such techniques as applying restrictions on how much a person should be, for example, permitted to lift. According to Gamberale *et al.* (1987), such quantifications are based on

a knowledge of the lifting capabilities of the human body and the characteristics of the lifting tasks. Probably the most well-known of quantification techniques is the NIOSH equation first developed in 1981 and later revised in 1991. According to Waters *et al.* (1993), both the 1981 and 1991 lifting equations are based on three criteria derived from the scientific literature and the combined judgement of experts from the fields of biomechanics, psychophysics and work physiology. However, due to the large variation in strength capabilities of the working population, such objective restrictions do have their faults in that they are not able to deal with inter-individual differences. In fact, MacKenzie (1992) claims that despite screening and increased safety regulations, the industrial back pain problem has increased.

#### **4) Design/Redesign of Work Stations**

A more costly method aimed at the prevention of musculoskeletal injuries is that of workplace design/redesign. According to Snook (1987), most authorities feel that this is the preferable approach although industrialists are inclined to prefer a more cost-effective solution. In 1978 Snook claimed that job design/redesign could however, only hope to suppress up to one third of the occupational injuries in the work environment. Similarly, Lutz and Hansford (1987) indicate that while engineering modifications are necessary for effective medical care management, the application of these modifications will rarely eliminate the problems of cumulative trauma disorders. In addition, Snook (1987) highlights that although job design may be applicable to many manufacturing operations, there are jobs that are difficult to design and control, such as fire-fighters and certain construction and delivery operations. Genaidy *et al.* (1990) also argue that engineering controls may not

always result in a satisfactory solution to the control of manual materials handling injuries due to several factors. These include the impracticality of redesigning certain industrial tasks because of cost considerations, limited work space availability and interference with existing job processes.

## 5) Back Schools

Another approach in the prevention of low-back pain at the workplace has been the education and training of workers in work methods and manual handling (Parnianpour *et al.*, 1987; Dul and Hildebrandt, 1987; Girling and Birnbaum 1988). As a result of the epidemiological evidence linking lifting and low-back pain, measures specifically related to lifting have been targeted in order to improve the method of lifting through instruction in technique. Although Tang (1987) claims that safety training in manual materials handling has been in practice in the developed countries for a while and that the importance of such training in reducing physical and mental stress is generally accepted, Girling and Birnbaum (1988) challenge this belief. These authors maintain that training introduces the idea of the "correct lift" which keeps the back straight and bends the knees and yet the incidence of low-back disorders amongst workers remains high. In 1972 Brown (cited in Girling and Birnbaum, 1988:479) stated: "In spite of this intensive and almost universal programme, the number of back injuries ... has remained about the same." Reports of consistently high figures of low-back pain cases suggest that training is ineffective. According to Chaffin and Park (1973) the scientific basis and validity of such an approach should therefore be questioned.

This is understandable as there can be no one single "correct" method to lifting, the emphasis

should rather be on educating the individual on general principles and on what to avoid. In line with this idea a phenomenon known as *Back Schools* evolved which, conducted by trained physiotherapists, aimed to give individuals suffering from low-back pain the confidence to cope with their back troubles on their own, to avoid excessive therapy, and to decrease the expense for themselves and society. Back Schools varied but they all included the goals of teaching proper lifting methods, effective body mechanics, and the safe use of the back in all lifting activities. Initially it was hoped by industry that Back Schools would literally end back problems and in fact, many industries found that there was a marked reduction in the reporting of back injuries. However, according to Isenbarger (1991), over time these same industries found that there was a gradual increase in the number of injuries, at times returning to the original level. Therefore, although the concept of Back Schools became extremely important, it was not to be a panacea for the elimination of back problems from the workplace.

#### **6) Physically Conditioning Workers**

The basis of exercise intervention for musculoskeletal injuries is that of the classical study of Cady *et al.* (1979) who reported that firefighters with good physical conditioning had fewer subsequent back injury reports than those firefighters with lower physical fitness levels. The authors thus concluded that physical fitness and conditioning have a preventative effect on back injuries.

In 1984 Asfour and his associates introduced the concept of physical training programmes as a means to control over-exertion injuries by improving worker's physical capabilities.

These authors studied the effects of training on muscular strength in individuals' engaged in manual lifting and holding by applying the concept of progressive resistance exercise. Results showed that both dynamic and static strength increased significantly during the course of training.

In 1989 Genaidy and associates speculated that by increasing a worker's physical capabilities, especially those of the new employees, one could hope to reduce the incidence of manual materials handling injuries, specifically low-back pain, since NIOSH (1981) had stated that a lack of physical fitness was one of the possible contributing factors to the etiology of back pain. The results of their study indicated that this was indeed possible.

Several other studies have also examined the effects of physical training on various aspects of a worker's physical capabilities (Sharp and Legg, 1988; Genaidy *et al.*, 1990; Genaidy, 1991; Genaidy *et al.*, 1992; Lindström *et al.*, 1992; Leino, 1993). Most of these studies demonstrated a significant increase in the physical capacity of subjects during the course of training.

However, despite improved medical care, increased automation within industry, more extensive use of pre-employment examinations and training, the establishment of acceptable handling limits, and the application of ergonomic principles to job design or redesign, scientific evidence as to the effectiveness of these techniques remains to be presented. More specifically, their failure to curb back problems is evidenced by the increasing incidence of related disability awards. The treatment of low-back pain and other musculoskeletal disorders has therefore become an ever increasing area of focus.

## TREATMENT METHODS

Despite the controversy surrounding the etiology of low-back pain a great deal has been learned over the past four decades. Possibly one of the most important conclusions, noted by Nachemson in 1976 and reiterated since by others (Mackenzie, 1992; Oldridge, 1995), is that surgery for low-back pain is very rarely needed. In addition, there exist some fairly well-controlled studies all demonstrating that very few, if any, treatments available are superior to nature's own course, specifically because the origin of low-back pain remains so obscure (Nachemson, 1992).

However, regardless of cause or duration of absenteeism, it is clearly evident that occupational low-back pain interferes with an individual's ability to work. In addition, the recurrence of back symptoms are noted to be as high as 85% with most recurrences taking place during the first two years after the initial injury. It is for these reasons that an emphasis not only on prevention but also early rehabilitation is so important.

### 1) Occupational Rehabilitation

According to Isenharzen (1991), occupational rehabilitation as a multidisciplinary body of knowledge and clinical application is a relatively new area of formal enquiry. However, this author argues that a physical therapist's contribution to work injury management precedes the development of *occupational rehabilitation* because since the 1970's physical therapists have treated musculoskeletal injuries within their clinics. Unfortunately with no understanding of the cause, physical therapists treated only the physical symptoms. The

missing entities were prevention, analysis of the mechanism of injury, and discharge before full rehabilitation was realised and ergonomic recommendations made (Isenhargen 1991, Greenberg and Bello, 1996).

"In the 1980's, pressure from industry and worker's compensation systems raised an awareness that merely treating the injured anatomy was not enough for a satisfactory return to work result." Isenhargen (1991:p73).

Although this led to a change in philosophy, it is only recently that there has been a shift in the goal of physical therapy to a *return to function* rather than mere pain relief. The idea of *functional restorative exercise* thus evolved as the physical therapist began to address the discrepancy between the functional ability of an injured worker and the physical requirement for work. Improved musculoskeletal functioning was seen as the goal so that rehabilitative exercise focused on that which would build overall musculoskeletal function (Isenhargen, 1991).

From this form of rehabilitation there is a natural transition into the work model. The functional outcome of rehabilitation is an elevation of a worker's physical level to a return to work status. In order to achieve this status, the actual components of a person's work must be integrated into the rehabilitation. According to Lanes *et al.* (1995), what was thus the first attempt, on a large scale, at rehabilitating patients with chronic injuries through multidisciplinary programmes, has today evolved into an approach which stresses physical rehabilitation and work-hardening.

## 2) Work-Hardening Programmes

Although studies of the etiology and maintenance of musculoskeletal injuries within different occupations show complex interactions amongst ergonomic, work organizational, psychological, educational and psychosocial factors, Gerdle *et al.* (1995) maintain that work-hardening programmes have proved to be effective in dealing with work-related musculoskeletal injuries.

Work-hardening programmes are an example of the *functional approach* to rehabilitation and, according to Hart *et al.* (1994), Voaklander *et al.* (1995), and Greenberg and Bello (1996), have been defined as highly-structured, interdisciplinary, goal-oriented, individualized treatment programmes designed to maximise the injured individual's ability to return to work. Robert *et al.* (1995) explain how work-hardening programmes have two phases - the general physical reconditioning phase and the specific job simulation phase. Because back pain, or any musculoskeletal injury, leads to a variety of degenerative problems associated with inactivity, such as muscular atrophy and cardiovascular deconditioning, the objective of the first phase is to reverse the deconditioning syndrome through specific flexibility, weight training and cardiovascular protocols. The second phase addresses the critical physical demands of the worker's job by simulating these demands in a clinical setting. Another aspect of work-hardening is modified work behaviour. Work-hardening programmes use real or simulated work activities designed to restore physical, functional, behavioral and vocational functions (Greenberg and Bello, 1996). According to Hart *et al.* (1994) the rehabilitation programme can thus progress from the clinical setting to the workplace and allows one to address the issues of worker behaviour in addition to physical tolerances.

McQuade *et al.* (1988) conducted a study of functional restoration in low back injury patients and found that 87% of the functional restoration group were actively working after two years compared with only 41% of the non-treatment group. Similarly, Lindström *et al.* (1992) compared the mobility, strength and general physical fitness between patients receiving only traditional care, and those receiving traditional care plus a graded activity programme incorporating behavioural therapy with the endpoint being return to work. They found that the patients in the activity group returned to work earlier than the patients in the control group, and that the patients in the activity group were more physically conditioned than those in the control group.

Studies such as these prompted Robert *et al.* (1995) to assess improvements in cardiovascular fitness and muscular strength after a 6-week work-hardening programme and to compare the physical fitness levels between those who returned to work and those who did not immediately return to work after the work-hardening programme. Although there was no statistical difference in the physical fitness levels between those who returned to work immediately and those who did not, the analyzed data demonstrated a substantial improvement in cardiovascular fitness and muscular strength following the 6-weeks of work-hardening.

The impact of work-hardening programmes is thus that an injured worker admitted to the programme is evaluated with a goal to a rapid, safe return to function through comprehensive rehabilitation. According to Voaklander *et al.* (1995), as a result of the demand for this type of service, over 300 work-hardening programmes have been accredited in the United States and Canada.

The fact that work-hardening programmes have something to offer in terms of prevention would therefore seem obvious, but as of yet this fact has not been fully recognised.

#### PROACTIVE WORK-HARDENING PROGRAMMES

According to Bigos *et al.* (1992), it is because of the lack of knowledge concerning the etiology of low back pain and because back pain is so multifactorial in origin that the effective prevention and treatment of lower back pain within industry has been undermined. An optimal approach to lower back pain must therefore include variables related specifically to the work environment so that the relationship between work, back pain and resulting disability can be better understood.

This concern is especially applicable in developing countries like South Africa, where the worker remains the most important sector of the community with his/her general well-being an essential element in the economic and social development of the country as a whole, and where the magnitude of occupational disease and injury has not been fully appreciated.

South Africa therefore needs to analyze the social, medical and economic issues surrounding musculoskeletal injuries such as lower back pain, and realise the need for the control of these occupational injuries. Government and industry must emphasise preventative medicine and primary health care rather than rehabilitative medicine in an attempt to prevent the ongoing social and economic disaster of injuries related to the workplace.

With respect for this need, work-hardening programmes could offer a prophylactic approach

in which to reduce the extent of musculoskeletal injuries within industry. These programmes traditionally aim to return the injured employee to work in a relatively short time with the progressive use of graded work-simulation tasks, training in proper body mechanics, stretching and strengthening exercises, educational programmes, as well as aerobic activities to increase cardiovascular fitness and endurance (Greenberg and Bello, 1996).

However, if injuries are partly caused by an individual's physical inability to perform the task required, the use of work-hardening programmes to improve worker physical capability, through both physical conditioning and work-simulated exercises, **before** the injury occurs, could prove effective as a proactive endeavour to reduce the extent of occupational injuries within local industry.

In 1994 Genaidy and his associates investigated the effects of a job-simulated exercise programme on employees performing manual handling operations. The effects of training were evaluated in terms of static and dynamic strength, endurance time and ratings of perceived exertion. The results demonstrated an improvement in all of the factors measured. A study conducted by Leino *et al.* (1994) examined changes in physical conditioning, health and physical work capacity after a worker-oriented physical fitness course arranged for lumberjacks experiencing low-back pain, yet still at work. The one-week courses were designed to activate exercising during leisure time and consisted of physical fitness tests, various types of exercise and lectures. The study is mentioned because of its use of lectures to supplement the physical training as well as the fact that the training took place during leisure time. In the intervention group, *perceived physical conditioning, health and physical work capacity* improved whilst an *ergonomic stress index* at work decreased. Both groups



reported an increased frequency of leisure-time physical activity and in a 6-month follow up, muscle function had improved in the intervention group, although no change was observed in aerobic capacity. There was also a tendency for the frequency of back pain-related sickness leaves, but not their duration, to develop more favourably in the intervention group.

In addition, the work-hardening programme offers the opportunity to address worker behaviour. It is therefore possible that the multifactorial etiology of injuries, such as low-back pain, may be better understood and therefore better controlled in the future.

### **Physical Work Capacity as a Focus of the Work-Hardening Programme**

According to Fisher and Jensen (1990), it has been known for years that muscular strength and cardiovascular fitness are integral components of optimal performance. If this is the case, then physical conditioning in order to improve the physical work capacity, specifically the muscular strength and cardiovascular fitness of workers, should facilitate a more efficient performance of physically demanding tasks and a resultant reduction of musculoskeletal injuries.

Indeed, Chaffin and Park (1973) reported on a longitudinal study of low back pain and found during the one-year follow-up period that the incidence rate was approximately three times greater in individuals who were unable to demonstrate strength equal to or greater than that required by the job, as compared to individuals demonstrating greater relative strength.

In fact, the definition of strength, *the ability to apply force*, implies its importance to

performance particularly in the lifting of objects. In industry all movements are essentially performed against some resistance. As Fisher and Jensen (1990) highlight, muscular strength also plays an important role in protecting individuals from injury because strong muscles not only increase body control and thus the ability to avoid injury, but also increase joint stability.

Likewise, Reimer *et al.* (1994) reports that the results of several studies have identified the importance of trunk strength in relation to low back pain. Prospective employees with lifting strength capabilities at or below the requirements of strenuous manual materials handling tasks are therefore at increased risk for sustaining low back injury.

In addition, manual materials handling tasks in general require a high energy release for a prolonged period of time. This energy for the phosphorylation of adenosine diphosphate (ADP) to adenosine triphosphate (ATP) is provided by the aerobic breakdown of carbohydrates, fats and proteins. In order for this high energy output to be maintained it is essential that the cardiovascular system provide the muscles with a continuous stream of nutrients and oxygen. Unless a steady rate can be achieved between oxidative phosphorylation and the energy requirements of the body, fatigue quickly ensues. According to McArdle *et al.* (1991), the ability to sustain such a high level of physical activity without undue fatigue depends on two factors:

- 1) The capacity and integration of the various physiologic systems for oxygen delivery, and
- 2) The capacity of the specific muscle cells to generate ATP aerobically.

According to Curtis *et al.* (1994), dramatic gains in task performance capability cannot be

expected unless the work-hardening programme incorporates combined aerobic and strength components. Isokinetic strength assessment can therefore play an important role in industrial rehabilitative and prophylactic work-hardening programmes by greatly improving the process of assessing the strength and prescreening applicants for vigorous manual labour. Similarly, assessing the cardiovascular fitness of employees is equally important.

### **Isokinetic Strength Testing**

The term *isokinetics* denotes the type of muscular contraction which accompanies a constant angular rate of limb movement, rather than a constant linear rate of muscle shortening.

Isokinetic devices, like the **CYBEX 6000** used in the present study, allow individuals to exert as much force and angular movement as they can generate up to a predetermined velocity. The **CYBEX 6000** is a relatively newly developed isokinetic device with an updated dynamometer and computer generated reports allowing measurements of torque, work and power. It is an accurate and clinically efficient extremity testing and rehabilitation system. When a limb's angular rate of movement equals or exceeds the preset velocity limit, the dynamometer produces an equalling counterforce to ensure a constant movement rate (**CYBEX 6000** User's Guide, 1991-1993).

Isokinetic resistance has several advantages over other testing modalities. Isokinetic testing allows one to quantify a muscle group's ability to generate torque or force; a muscle group may be exercised to its maximum potential throughout an entire range of motion; and isokinetic resistance provides a safer alternative to other testing methods because the dynamometer's resistance mechanism essentially disengages when pain or discomfort is

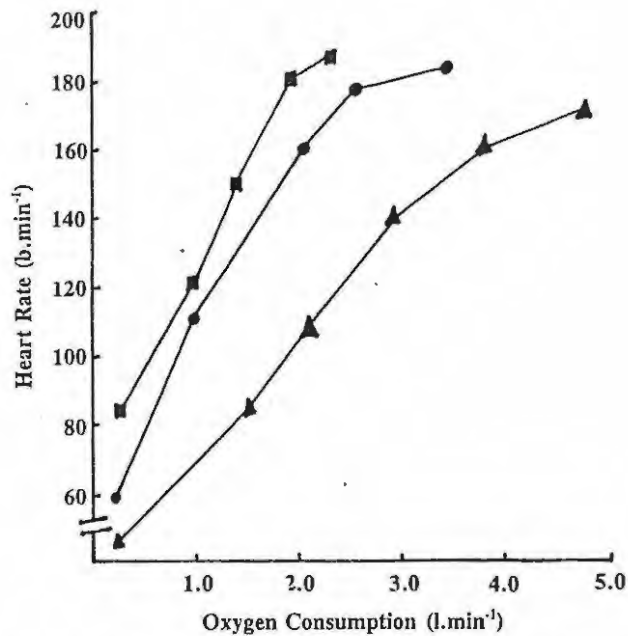
experienced by the subject (Perrin, 1993).

Peak or average torque values are the isokinetic parameters most frequently used to assess human muscle performance and allow one the chance to assess the effect of specific exercises on the functional ability of certain muscles. Such testing is therefore of great value in assessing the effect of a work-hardening programme on the muscular strength of an individual.

### **Cardiovascular Measures**

Maximum heart rate values relate to age and can be predicted using the formula:  $220 - \text{age} = \text{maximum predicted heart rate}$ . These predicted values are independent of race, gender or age. Fisher and Jensen (1990) however, emphasize that heart rate is affected by a wide variety of factors especially age, and that responses will vary depending on the type of work being done. The use of smaller muscles such as the arm muscles during heavy lifting will increase the heart rate out of proportion to the metabolic need. *Figure 2* represents the essentially linear relationship between heart rate and oxygen consumption and demonstrates how with cardiovascular conditioning the working heart rate at any given oxygen consumption is reduced.

With an increase in heart rate there is an increase in systolic blood pressure. Blood pressure is very simply the mathematical product of cardiac output and peripheral resistance. At rest systolic pressure (pressure generated by the heart during contraction) is on average 120mmHg and diastolic pressure (the relaxation phase of the cardiac cycle) is 80mmHg. Due to the fact that blood pressure increases with manual labour as a result of the increase in the



**Figure 2:** Heart rate in relation to O<sub>2</sub> consumption during upright exercise in endurance athletes (▲) and sedentary college students prior to (■) and following (●) 55 days of aerobic training (from Saltin, 1969).

amount of blood being pumped throughout the body it is important that a worker not suffer from hypertension, where systolic pressure at rest may be as high as 250 or even 300mmHg, and diastolic pressure may be elevated above 90mmHg, as this imposes an excessive strain on the normal functioning of the cardiovascular system (Fisher and Jensen, 1990; McArdle *et al.*, 1991).

The testing of muscular strength, specifically of the trunk, as well as the efficiency of the cardiovascular system, are therefore highly valuable assessments for industrial workers given the incidence of occupational injuries and low-back pain. This fact underscores the importance of screening individuals for strength of trunk musculature together with cardiovascular fitness and implementing appropriate exercise programmes for those with deficits.

## THE ROLE OF ERGONOMICS IN SOUTH AFRICA AND OTHER DEVELOPING COUNTRIES

According to Elgstrand (1985), many developing countries are characterized by a vicious circle of low productivity, low salaries, malnutrition, diseases, and low physical working capacity. Ergonomics, like occupational safety and health, should therefore contribute to the breaking of this circle in order to create safe working environments; promote the health of the workers by preventing occupational disease and injury; prevent problems of unnecessary fatigue and ensure the proper utilisation of human capabilities. Ergonomics utilised in this manner within South Africa could thereby promote the increased well-being of the local worker and improved productivity of the country.

According to Asogwa (1987), individuals involved in the field of ergonomics should be concerned with the acquiring of national injury statistics within industries; unions should be encouraged to take more of an interest in health and safety at work through conferences, seminars, workshops and short courses, rather than being preoccupied with salary increases; government should ensure that new machinery brought in from industrialised countries should include as part of the deal, relevant courses in instrumentation and maintenance engineering; and research institutes should be encouraged to collect data on national occupational safety and health.

In short, developing countries need to recognise the essential role of ergonomics in maintaining the health and safety of the worker and in increasing the productivity of the country.

## CHAPTER THREE

### METHOD

#### INTRODUCTION

It has been well established that occupational musculoskeletal disorders, specifically low-back injuries are recognized as a major medical, social and economic problem worldwide and that despite the magnitude of the problem there are no standardized protocols for the diagnosis, reduction or treatment of these injuries in industry.

Tests of individual physical work capacity for work entailing heavy manual exertion are a rarity in practice, especially within the developing countries. People who apply for a job requiring heavy manual labour are those who believe themselves physically able for the task and self-selection is thus the normal rule. The result is a high incidence of occupational musculoskeletal injuries, specifically within labour-intensive working environments like South Africa where physically demanding tasks predominate.

Occupation-specific work-hardening programmes which focus on the physical work capacity of labourers through an integrated approach of aerobic, strength and educational components could however, prove an effective strategy in both the prevention and rehabilitation of occupational injuries like low-back pain, thereby controlling the extent of this and other musculoskeletal injuries within developing industrial nations like South Africa.

## EXPERIMENTAL DESIGN

The central purpose of this study was an holistic analysis of the effect of a work-hardening programme on the physical work capacity of manual labourers in South African industry.

For this reason a **one group pre-test - post-test** design was used:

$$O_1 \quad T \quad O_2$$

where:

O is the test or observation and subscripts refer to the order of testing,  $O_1$  is the pre-test, whilst  $O_2$  is the post-test.

T is the treatment applied (in this case the involvement in an occupation-specific work-hardening programme).

Such a design allows for the observation of any change in the dependent variables, namely cardiovascular, strength and perceptual measures, as a result of the manipulation of the independent variable, that is the proactive work-hardening programme.

## SUBJECT CHARACTERISTICS

Initially forty Black and Coloured male manual labourers between the ages of 20 and 50 years, engaged in physically demanding tasks within three local Grahamstown industries, formed the sample for this study. However, at completion of the project, only twenty-five

of these subjects were still involved in the study.

**Table IV:** Number of subjects from each of the three industries.

|                                    | NUMBER OF SUBJECTS |          |
|------------------------------------|--------------------|----------|
|                                    | INITIAL            | ULTIMATE |
| INDUSTRY ONE (DAIRY)               | 19                 | 13       |
| INDUSTRY TWO (WHOLESALE WAREHOUSE) | 9                  | 5        |
| INDUSTRY THREE (BOTTLING COMPANY)  | 12                 | 7        |

## RESEARCH PROTOCOL

### INFORMED CONSENT

An initial letter (see Appendix A) was sent to a number of local businesses in Grahamstown explaining the purpose of the research and requesting that should these businesses be interested in the reduction of musculoskeletal disorders within industry that they encourage their workers to volunteer for the study.

This letter was followed up with a personal meeting with the management of those industries who expressed an interest in the research in order to provide them with additional information, answer any queries they may have had, as well as to request that management explain the general concept of the research, and the voluntary basis of involvement in the study (i.e. subjects who did volunteer would be free to withdraw at any stage) to their

workers.

Workers involved in strenuous physical occupational tasks and who were interested in the project, were provided with a short information sheet (see Appendix A) regarding the aims and details of the research. Any queries the subjects had were answered and those workers interested in the research then signed the informed consent form (see Appendix A) thus forming the sample group for the study.

#### **PILOT STUDY**

A pilot study was conducted prior to the commencement of data collection. As the equipment and tests used are internationally accepted as valid and reliable, the pilot study was simply required to establish a logical order of testing, familiarity with the equipment and the establishment of the overall protocol. The subject for the pilot study was a Black male fluent in Xhosa. His experience as a subject during the pilot study was invaluable as he was able to assist in the setting up and administering of the tests. In addition, he was able to explain the Rating of Perceived Exertion scale (see Appendix B) to the subjects in Xhosa and was thus also able to assist in the obtaining of the subjects' perceptual responses. The pilot study only involved the isokinetic strength testing on the **CYBEX 6000**. The author was thus familiar with the testing procedures and the equipment ensuring that the data were collected reliably and consistently.

## MORPHOLOGICAL DATA

### Stature and Mass

Stature was only measured at the pre-conditioning test session whilst mass was measured at both the pre- and post-conditioning test sessions at the Department of Human Movement Studies. These anthropometric variables provide information on overall body size; stature being a major indicator of general body size and of bone length, whilst mass provides a composite measure of total body size. Besides being essential in the assessment of relative strength on the isokinetic dynamometer, ratios can also be constructed from these two variables. Mass and stature combine to form indices that are closely related to body fat, the best known index being the **Body Mass Index (BMI)**, or **Quetelet Index**, which is used to assess mass relative to stature and is calculated by dividing body mass in kilograms by stature in metres squared ( $\text{Mass}/\text{Stature}^2$ ). BMI is a good indicator of total body composition and is reported to be closely related to health outcomes (Chumlea and Roche, 1988; ACSM, 1991).

Stature was measured by means of a stadiometer. The subjects were all measured barefoot with their body weight distributed evenly on both feet. Arms hung freely by the sides of the trunk with palms facing the thighs. The subjects placed their heels together and attempted to have them as close to the vertical as possible. The scapulae and buttocks were in contact with the vertical. With the head positioned in the Frankfurt Horizontal Plane subjects were asked to inhale deeply and maintain a fully erect position without altering the load on their heels. The moveable head board was then brought onto the vertex with sufficient pressure

to compress the hair.

Due to cultural reticence to removing their clothing, subjects were weighed in their overalls and were asked to remove only their shoes. Clothing was similar for pre- and post-conditioning testing and comparisons were therefore acceptable. The subject stood still over the centre of the platform of the Seca scale with body weight evenly distributed between both feet.

## CARDIOVASCULAR MEASURES

### Heart Rate Responses

Heart rate is simply the number of times the heart contracts every minute and allows one a simple measure of the body's capacity for oxygen delivery. Due to the fact that the cardiovascular system becomes more "efficient" as a result of physical training, pre- and post-conditioning heart rate responses provided a convenient index to measure training improvements following participation in the work-hardening programme. Although training adaptations are complex they manifest in several ways; a decrease in resting and submaximal heart rates, as well as a reduction in recovery time (Fisher and Jensen, 1990).

Heart rate responses were measured with the use of the **UNIQ** heart watch, a portable heart rate monitor which utilizes the electrical activity of the heart to measure and store heart rate data. The heart watch consists of three components; the watch, an electrode strap and a transmitter.

The heart watch was fitted around the subject's wrist, whilst the electrode belt, an elasticated strap, which contains the transmitter connectors on the front and two conductive rubber electrodes on the back, was placed around the chest at the level of the inferior border of the pectoralis major muscles. The transmitter was then fixed to the electrode strap using the press studs on the strap with the red press stud on the subject's left, over the region of the heart.

### **Resting/Reference Heart Rate**

Reference heart rate was recorded during both the pre- and post-conditioning test sessions held at the Department of Human Movement Studies. According to the ACSM (1991), resting heart rate may be reduced by approximately 10 to 15b.min<sup>-1</sup> following a period of aerobic conditioning. The heart of the conditioned individual can thus do more work in fewer beats.

Due to the fact that the lowest resting heart rate is found when a person rests in a supine position (Fisher and Jensen, 1990) reference heart rate was monitored and recorded by means of the UNIQ heart watch whilst the subjects rested in a supine position for a few minutes. Although this measure may be regarded as a resting heart rate value it is termed the reference value to accommodate for any possible anxiety the subjects may have been feeling which would have resulted in an increase in their resting heart rate.

### **Working Heart Rate**

One of the most obvious changes that occurs during any form of physical activity is an increase in heart rate because as work intensity increases more blood is needed to supply

oxygen to the working muscles (Mc Ardle *et al.*, 1991).

**Working** heart rates were measured both *in situ* and during the laboratory testing by means of the **UNIQ** heart watch. The heart watch allows the recorder to store data within the watch's memory. By pressing the **PROG** button on the watch twice, the **stop watch** and **heart rate programme** are selected. The **MODE** button is then pressed twice to display the **sample rate**. Using the **ENTER** button the **stop watch** and **data storage** are initiated and when required, terminated by pressing the **MODE** button.

For the purpose of the study, *in situ* heart rate data was stored every 15 seconds for a period of 30 minutes during the subject's working day whilst the subject executed a specific lifting task. An **average** as well as a **peak working** heart rate were then calculated. **Average working** heart rate was calculated as the mean heart rate recorded over the half hour period, whilst **peak working** heart rate was simply the highest working heart rate recorded over the same time. During the laboratory testing, a **working** heart rate was recorded after each velocity of isokinetic trunk flexor and extensor strength testing (i.e.  $60^{\circ}.\text{sec}^{-1}$  and  $120^{\circ}.\text{sec}^{-1}$ ).

### **Recovery Heart Rate**

The rate of recovery to physical activity was assessed using the Harvard Step Test. The purpose of this test was to use measurement of **recovery** heart rate from a standardized exercise bout as a rough means of assessing cardiovascular efficiency. The heart rate of the conditioned individual not only increases less during strenuous work but also recovers faster (Barrow and Brown, 1988).

The Harvard Step Test is useful in separating well from poorly conditioned individuals in situations where both categories are found in a large group such as the present study. The step test requires the subject to stand facing a 50cm bench. A cadence of 120 beats per minute is then established in order to produce 30 steps per minute (two counts to stand up on the bench, two counts to return to the floor). The subject is required to step up and down with the same lead leg to the following plan: up, up, down, down thus establishing a steady rhythm. The lead leg can be altered occasionally, but continuous alteration of the lead leg is not permitted. The subject is expected to extend his legs and back fully as this ensures the work done is standardised.

If the subject was unable to endure the task for five minutes, he was made to sit down and his time was recorded. His pulse count was taken from one 30 second count (60 - 90s after exercise) and he was scored using the following formula:

#### Short-Form Scoring

$$\text{score} = \frac{\text{duration of exercise (s)} \times 100}{5.5 \times 30\text{s pulse count}}$$

If the subject was able to complete the full five minutes his pulse rate was counted for 30 seconds at:

1 minute after exercise (60 - 90s)

2 minutes after exercise (120 - 150s)

3 minutes after exercise (180 - 210s)

The sum of these three thirty-second pulse counts was then used in the following formula:

#### Long-Form Scoring

$$\text{score} = \frac{\text{duration of exercise (s)} \times 100}{2(\text{sum of 3 30s pulse counts in recovery})}$$

Table V represents the norms for the Harvard Step Test.

**Table V:** Ratings for the Harvard Step Test.

| SCORE        | RATING        |
|--------------|---------------|
| 100 or above | excellent     |
| 90 - 100     | very good     |
| 80 - 89      | above average |
| 70 - 79      | average       |
| 60 - 69      | below average |
| 55 - 59      | poor          |
| below 55     | very poor     |

(from Brouha, 1943)

### Blood Pressure

According to the ACSM (1991) both systolic and diastolic blood pressure tend to be reduced moderately at rest and during submaximal exercise after regular participation in an aerobic conditioning programme. The largest decreases tend to occur in systolic pressure and are most apparent in hypertensive individuals.

Blood pressure was measured in millimetres of mercury by means of a sphygmomanometer with a stethoscope placed over the brachial artery. The pressure cuff was inflated so that its

pressure exceeded the systolic pressure within the brachial artery. Blood flow was thus occluded so that the brachial pulse could no longer be heard. The pressure within the cuff was then reduced by small increments until a faint sound was detected. This represents blood flowing through the brachial artery, and the pressure exerted on the walls is known as systolic pressure. As the pressure in the cuff was further lowered, distinct sounds continued to be heard as the blood flowed through the artery for long portions of the cardiac cycle. The pressure in the artery when the sound disappeared was a measure of diastolic pressure.

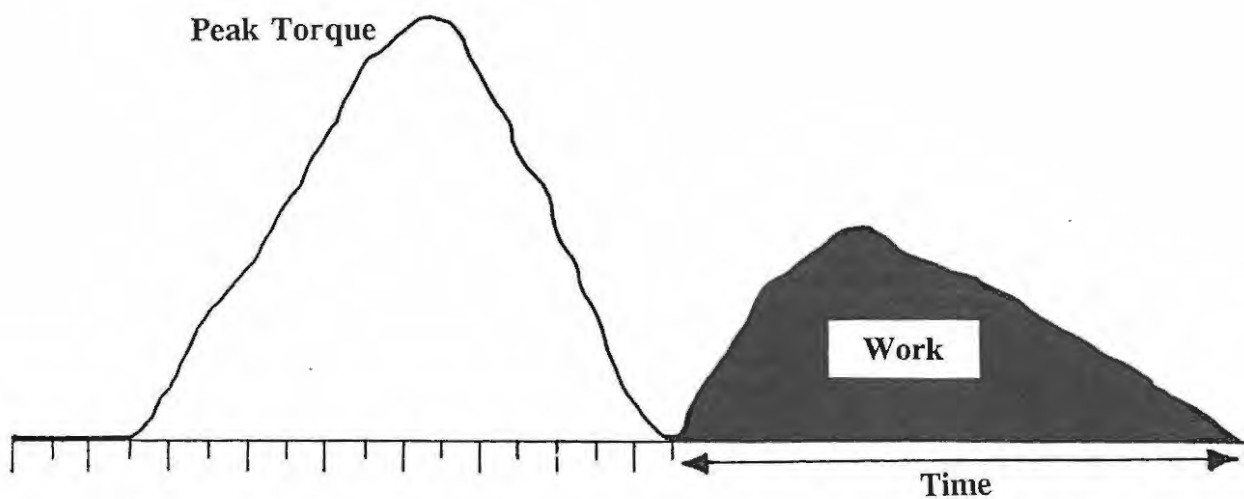
#### STRENGTH MEASURES

One of the most remarkable features of the human body is its ability to adapt, both short- and long-term, to physical stresses. However, injuries occur when the body is no longer able to adapt to these stresses resulting in a breakdown within the tissues or system. The basic principle behind preventing the occurrence of occupational injuries is therefore to either keep potentially harmful agents from reaching workers in amounts or rates that exceed injury thresholds (Haddon and Baker, 1981), or to improve the workers physical ability to cope with the demands of the task (Genaidy *et al.*, 1992; Waters *et al.*, 1993).

The **CYBEX 6000** dynamometer, an isokinetic device, was used to objectively quantify the musculoskeletal performance of the right arm by assessing grip strength, and also the extensors and flexors of the trunk. The **CYBEX 6000** provides isokinetic measurement of dynamic musculoskeletal performance by allowing the subject to exert as much force and angular movement as possible at a predetermined velocity. Once the body segment's angular rate of movement equals the preset velocity limit, the **CYBEX 6000's** dynamometer produces

an equalling counterforce to ensure a constant rate of movement while at the same time measuring the force generated. One is then able to quantify a muscle group's torque, work and power.

This study made use of three measurements: peak torque, total work and average power. When the torque produced by a muscle is assessed throughout the entire range of motion, the measurement may be reported as either the peak or average value. The peak value is the point in the range of motion where the greatest torque is produced. If the force and distance of a given muscle contraction are known, the amount of tension produced by the muscle may be expressed as work. If the quantity of time required to produce work is known, the ability of the muscle to generate power may be determined (Perrin, 1993). Due to the diversity apparent amongst the subjects' physiques, relative strength measures were recorded for the discussion. *Figure 3* illustrates peak torque, work and power as indicated by normal isokinetic torque curves.



**Figure 3:** Normal isokinetic torque curves representing peak torque, work and power. Peak torque is the single highest point of the torque curve, work is the total area under the torque curve, and power is the time required to perform work (from Perrin, 1993).

A point that must be clarified is the misconception that assessment of peak torque at slow isokinetic test velocities reflects strength and the torque produced at higher test velocities represents power. Determination of torque, work and power is *independent* of test velocity.

## Grip Strength

The grip strength data was measured at a velocity of  $30^{\circ}.\text{sec}^{-1}$  in accordance with the guidelines set out in the CYBEX 6000 User's Guide (1991-1993). Subjects stood facing the dynamometer with approximately a  $160^{\circ}$  angle at the elbow joint (see *Figure 4*) and were required to execute five maximum gripping actions with the right hand. The subjects were instructed not to make use of their body weight during the testing as this would have led to incorrect measures of grip strength.



**Figure 4:** The positioning of the subject during the isokinetic grip strength test.

## Trunk Strength

The **CYBEX 6000** Trunk Extension/Flexion Unit (TEF) was used to test the subjects' extensor (erector spinae) and flexor (rectus abdominous, external and internal obliques) muscles; muscles used in their everyday occupational tasks (see *Figure 5*). The TEF unit directly measures sagittal plane forces and range of motion as well as continuous dynamic strength at every point in the range of motion.



**Figure 5:** The positioning of the subject during the isokinetic trunk strength testing.

The trunk strength data was gathered in accordance with the guidelines set out in the **CYBEX 6000 User's Guide** (1991-1993). Velocities of 60 and 120°.sec<sup>-1</sup> were selected to test the extensor and flexor muscles as these velocities were thought to correlate closely with the

subjects' functional activities. In order to obtain a measure of "average work", the subjects were requested to repeat the tests five times per speed.

## PERCEPTUAL MEASURES

Ratings of perceived exertion were recorded during the *in situ* task analyses and immediately following the trunk strength tests in order to obtain a tangible assessment of the subjects' perceptions of the physical demands of their tasks as well as the strength testing.

### Rating of Perceived Exertion (RPE)

This perceived exertion scale provides a method to quantify subjective physical activity intensity. According to the ACSM (1991), RPE correlates closely with several exercise variables, including percent  $\text{VO}_2\text{max}$ , percent heart rate reserve, minute ventilation and blood lactate levels. The ACSM (1991) also claim that numerous clinical studies have demonstrated that the category RPE scale is a reproducible measure of exertion within a wide variety of individuals regardless of age, gender or cultural origin. For the purpose of the study the RPE scale was translated into Xhosa (see Appendix B).

Ratings of perceived exertion were collected *in situ* three to four times during the half hour period of task analysis as well as during the laboratory testing when they were collected at the completion of both the 60 and  $120^\circ.\text{sec}^{-1}$  trunk strength tests.

Bigos *et al.* (1986a) identified that one of the major thrusts of investigation into activities and events associated with the onset of low-back pain has been to identify tasks associated with a high incidence of back injury. One of the manual materials handling activities specifically identified has been lifting, a regular task in the industries selected in the present project.

Over the last few decades, researchers have investigated various methods of assessing and reducing the risks associated with lifting. In 1990, Charteris and Scott developed **liftRISK**, an expert system based on South African data. It is a basic, easy-to-use, first-phase identification of risk factors associated with lifting tasks. Because the two main components in any lifting task are the object to be lifted and the person required to lift the object, **liftRISK** requires the input of four task-related factors (mass, initial vertical height, horizontal distance and frequency) and four operator-related factors (age, back and arm strength and aerobic capacity). **liftRISK** then calculates a **task inherent risk** and a **predisposing operator risk**, the weighted interaction of which provide an **overall situational risk**. **liftRISK** will then suggest possible intervention strategies.

**liftRISK** analyses were performed on typical lifting situations within the three industries in order to identify sub-optimal performance conditions. The four task-related factors for each task were entered whilst default operator values were used instead of actual measured factors (see Appendix D). This was effected in order to make the assessments applicable to all the workers involved in the study. Once these factors were entered, **liftRISK** calculated the risk involved in each of the lifting situations according to inbuilt parameter limits (see *Table VI*).

Table VI: liftRISK - parameter limits.

| Task Parameter Limits                                      | LOW RISK    |      | HIGH RISK |     |
|--|-------------|------|-----------|-----|
|  | Mass (kg)   | 0    | 14        | 28  |
| Frequency (lifts.min <sup>-1</sup> ) *                     | 0           | 4    | 8         | 12  |
| Reach (cm)   | 0           | 30   | 60        | 90  |
| Stoop (cm)   | 72          | 48   | 24        | 0   |
| Stretch (cm)   | 72          | 114  | 156       | 198 |
| Operator Parameter Limits                                  | LOW RISK    |      | HIGH RISK |     |
|  | Age (years) | 20   | 35        | 50  |
| Arm strength (N)   | 770         | 590  | 410       | 230 |
| Back strength (N)  | 2400        | 1800 | 1200      | 600 |
| Aerobic capacity (ml.kg <sup>-1</sup> .min <sup>-1</sup> ) | 65          | 53   | 41        | 29  |

\* Mass-related frequency limits

Mass < = 5kg

Fmax = 24

Mass 5 to 55kg

Fmax = (-0.3\*mass)+(0.5\*mass max)

Mass > 55kg

Fmax = 1

The intervention strategies provided by liftRISK, together with the information gained from the *in situ* task analyses and pre-conditioning laboratory tests, were used in the compilation of the work-hardening programme.

## PROCEDURE

### PRE-CONDITIONING *IN SITU* TASK ANALYSIS

An initial *in situ* task analysis was conducted in order to investigate the demands of the workers' daily occupational tasks and to obtain a measure of their peak and average working

heart rates. The subjects were thus required to wear a heart watch for a 30 minute period during their working day whilst their task was analyzed in terms of: task rotation, duration of task, frequency with which the task was performed, lift rate per minute, whether work rate was self-paced or imposed, load container/specifications (dimensions, mass and shape) as well as lift specifics (vertical and horizontal placements) (see Appendix B). During this period the subjects also provided ratings of perceived exertion concerning the physical demands of their task.

#### **PRE-CONDITIONING LABORATORY DATA COLLECTION**

Once task analyses were completed, the workers were brought into the Department of Human Movement Studies, in two's and three's, where they participated in a pre-conditioning assessment (see Appendix C). This assessment always occurred in the morning so as to prevent fatigue (as a result of involvement in occupational tasks) from becoming a confounding factor during data collection.

These sessions lasted approximately one hour and dealt with the subjects' personal details such as their age, occupation (in present and previous employment), period of employment (present and previous), a medical history and physical activity questionnaire as well as a measure of stature and mass. These morphological measures were essential for the strength testing on the **CYBEX 6000** and in addition provided a profile of the physiques of the subject group.

Subjects participated in isokinetic strength testing on the **CYBEX 6000** in order to obtain a

measure of their right grip strength and trunk flexor and extensor strength. The grip strength test was performed five times at a velocity of  $30^{\circ} \cdot \text{sec}^{-1}$ , whilst the trunk flexor and extensor strength test was performed five times at a velocity of 60 and  $120^{\circ} \cdot \text{sec}^{-1}$ . The subjects were encouraged to give their maximum effort during all three of these tests over all five attempts.

The grip and trunk strength tests were performed randomly i.e. there was no specific order of testing, however, during trunk strength testing the subjects were always tested at  $60^{\circ} \cdot \text{sec}^{-1}$  first. There was a natural rest period between the grip and trunk strength testing as the different tests were set up, whilst a one minute rest was built into the testing protocol between the  $60^{\circ} \cdot \text{sec}^{-1}$  and  $120^{\circ} \cdot \text{sec}^{-1}$  trunk strength tests. Working heart rates as well as ratings of perceived exertion were recorded following both trunk strength tests.

A measure of the subjects' resting heart rates and blood pressure were collected between the strength assessment and the subjects' participation in the Harvard Step Test. The Step Test was used in order to assess their cardiovascular condition. The subjects were encouraged to complete the full five minute stepping test but were warned that should they feel faint or short of breath that they sit down immediately. To establish a steady stepping rhythm a metronome was used.

The *in situ* task analyses, the detailed graphic and numerical analyses of the subjects' musculoskeletal status provided by the **CYBEX 6000** together with the scores obtained from the Harvard Step Test were used in the assessment of typical working situations using **liftRISK**. This in turn helped in the design of an appropriate occupation-specific work-hardening programme.

## **THE WORK-HARDENING PROGRAMME**

The work-hardening programme was run twice a week, within each of the three industries, during the subjects' working day. The programme ran for a period of 30 minutes and consisted of two phases; a general physical conditioning phase and a specific job simulation phase.

### **The General Physical Conditioning Phase**

This phase concentrated on improving cardiovascular conditioning, as well as muscular strength and flexibility and therefore provided both aerobic activities and specific training in stretching and strengthening exercises.

Aerobic activities included a run outside the premises of the industry plus time spent within the premises in which each of the workers had the chance to contribute some form of aerobic exercise to the group, such as jogging-on-the spot, "jumping jacks" and skipping.

Strength training involved the use of free-weights, the subject's own body weight or resistance provided by a co-worker. Exercises concentrated on the arms, shoulders and chest areas (bicep curls, push-ups, "pec" exercises); the abdomen and lower back (sit-ups and trunk hyperextensions) as well as the legs (squats, with and without a partner, and lunges).

## **The Specific Job Simulation Phase**

This phase addressed the critical physical demands of the workers' jobs by simulating these demands during the work-hardening programme and then educating the workers in the proper body mechanics of executing a specific task.

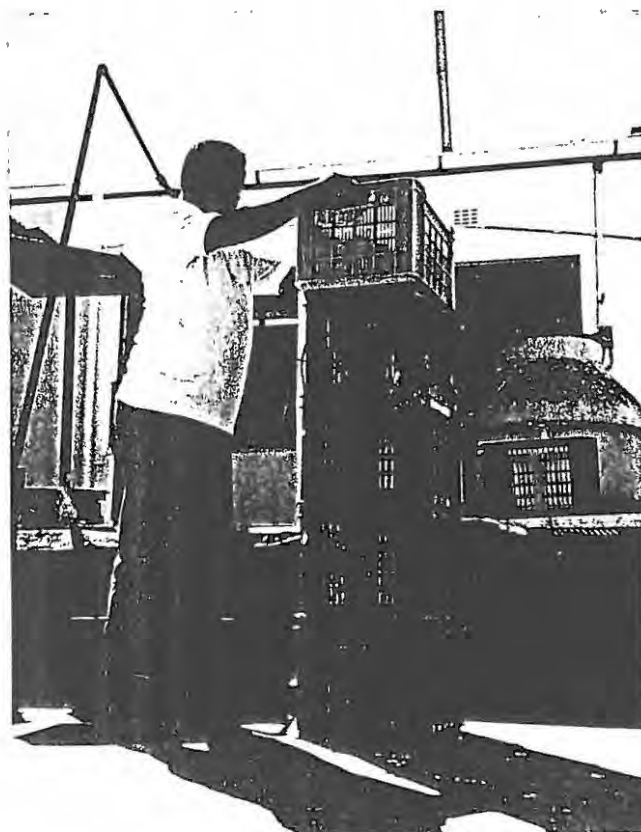
Due to task rotation and similarity of tasks within the industries, this phase concentrated on a different task each week. This meant that all the workers were trained in the execution of a number of different tasks. In addition, the work-simulation phase aimed not only at improving physical and functional behaviour but also behavioral and vocational functions by allowing the workers to discuss issues encompassing their tasks and suggesting that they help one another when a task is too physically demanding for one individual. In such a manner a team spirit was fostered which resulted, for example, in the establishment of a soccer team at the dairy.

*Figure 6* illustrates a subject being educated in proper body mechanics during the execution of a specific task. In this particular example the worker is being shown how to perform an asymmetrical lift with the use of his whole body i.e. he is told to move his feet and not twist his trunk.

## **Organisation of the Programme**

Initially the work-hardening programme was conducted as a group programme with everyone doing the identical exercise at the same time. During this "introductory" stage approximately

10 minutes was spent on aerobic activity, 15 minutes on strength training and task simulation and 5 minutes on flexibility.



**Figure 6:** The specific job simulation phase of the work-hardening programme.

However, once the workers were accustomed to the various activities, the area in which the programme was conducted was divided into various stations and each worker spent a period of 90 seconds at each station.

There were fifteen stations in total, although all fifteen were only made use of at the dairy as the subject numbers at the other industries were not high enough to warrant the use of all the stations. Each of the stations dealt with either an aerobic activity or some form of

strength training, whilst the last one incorporated a task simulation. Only one station was used for task simulation in order to prevent injuries due to lack of supervision. The workers were closely supervised to ensure that each activity was correctly performed.

#### POST-CONDITIONING LABORATORY DATA COLLECTION

Once the ten-week work-hardening programme was completed, subjects who had attended 80% and more of the sessions, were brought into the Department of Human Movement Studies where they again participated in the isokinetic strength testing on the **CYBEX 6000** and in the Harvard Step Test in order to assess the effectiveness of the work-hardening programme. Mass, reference heart rate and blood pressure were once again measured (see Appendix C). This testing session also lasted approximately one hour.

#### POST-CONDITIONING *IN SITU* TASK ANALYSIS

Finally, *in situ* task analyses (see Appendix B) were again conducted in order to document any improvements in the workers execution of their tasks, improvements in peak and average working heart rate as well as the workers' perception of their task demands. The subjects again wore a heart watch for a 30 minute period during their working day and provided ratings of perceived exertion concerning the physical demands of their task.

## STATISTICAL ANALYSIS

The Statgraphics statistical programme was used in order to obtain descriptive and two-sample analysis of the data. Descriptive statistics (mean, standard deviation, minimum, maximum, range and coefficient of variation) were performed on all the pre- and post-conditioning data in order to obtain a summary of the results whilst a series of related T-tests were performed using the pre- and post-conditioning data in order to establish whether any statistically significant differences existed between the cardiovascular responses, strength measures and perceptual responses.

The above statistics were performed in an attempt to falsify the null hypothesis that no difference would occur in the physical work capacity of the subjects following a ten-week involvement in a proactive work-hardening programme. The 0.05 level of probability was employed throughout the statistical treatments in this study in order to test the significance of differences between the pre- and post-conditioning data collected. This level of probability was chosen in order to minimise the possibility of committing a Type-I error, without increasing the possibility of committing a Type-II error.

## CHAPTER FOUR

### RESULTS AND DISCUSSION

#### INTRODUCTION

As an industrially developing nation, manual labour involving physically demanding tasks is commonplace within the South African workplace. Consequently, according to Von Tonder's (1988) South African statistics, musculoskeletal injuries are thought to be primarily as a result of overexertion where the worker exceeds personal physical capability limits.

Studies have however, shown that improved physical conditioning plays an important role in the reduction of occupational injuries, particularly lower back problems. The objective of this research was therefore to make an holistic examination of the effect of a prophylactic work-hardening programme on the physical work capacity of South African workers involved in physically demanding manual materials handling tasks.

The data are organised and presented in two main sections: general descriptive data of subject characteristics, followed by measures recorded at the pre- and post-conditioning test sessions, both *in situ* as well as in the laboratory. Although the results are presented in isolation, the ensuing discussion attempts to integrate and explain the findings of this study.

## GENERAL DESCRIPTIVE DATA

### SUBJECT CHARACTERISTICS

Initially forty Black and Coloured adult male volunteer manual labourers, presently employed at one of three local Grahamstown industries, formed the sample group for the study. However, due to influenza, vacations and non-adherence to the programme, only twenty-five subjects ultimately participated in the entire study. *Table VII* displays the number of subjects selected as well as the areas within each of the industries from which they were selected.

**Table VII:** Number and distribution of subjects within each of the industries.

| INDUSTRY             | AREA           | NUMBER OF SUBJECTS |
|----------------------|----------------|--------------------|
| Dairy:               | Factory        | 12                 |
|                      | Despatch       | 1                  |
|                      | TOTAL SUBJECTS | 13                 |
| Wholesale Warehouse: | Warehouse      | 3                  |
|                      | Receiving      | 2                  |
|                      | TOTAL SUBJECTS | 5                  |
| Bottling Company:    | Warehouse      | 1                  |
|                      | Truck Helpers  | 6                  |
|                      | TOTAL SUBJECTS | 7                  |

In recognition of the fact that workers who perform strenuous manual materials handling activities are at a greater risk of being injured, the subjects were selected on the basis of their involvement in occupational tasks of a physically demanding nature. The group ranged in age from 20 to 50 years, the mean age of the twenty-five subjects being 33.64 years (SD

7.55); the distribution of ages is presented in *Table VIII*.

**Table VIII:** Age distribution of the twenty-five subjects.

| AGE GROUP                           | FREQUENCY |
|-------------------------------------|-----------|
| 21-25                               | 4         |
| 26-30                               | 5         |
| 31-35                               | 7         |
| 36-40                               | 4         |
| 41-45                               | 2         |
| 46-50                               | 3         |
| $\bar{x}$ : 33.64<br>(S.D.): (7.55) |           |

Mention has already been made of the fact that measures of stature and mass provide information on overall body size and that ratios constructed from these pairs of anthropometric data provide a good indicator of physique (Chumlea and Roche, 1988). *Table IX* presents the morphological data of the group as measured at the pre- and post-conditioning laboratory test sessions.

The data illustrate that the group were of average height and mass although there was substantially more variation amongst the mass measurements than amongst the height measurements at both the pre- and post-conditioning test sessions. This fact describes the diversity of physiques present amongst the subject group as well as emphasising the need for relative rather than absolute isokinetic strength measurements in order to compare the strength performance of the subjects.

**Table IX:** Morphological data collected at the pre- and post-conditioning laboratory test sessions.

| DATA                                     |                        | CONDITION        |                 |
|--|------------------------|------------------|-----------------|
|  |                        | PRE              | POST            |
| Stature (m)                              | $\bar{x}$ :<br>(S.D.): | 1.68<br>(0.07)   |                 |
| Mass (kg)                                | $\bar{x}$ :<br>(S.D.): | 64.08<br>(10.99) | 64.04<br>(9.96) |
| Body Mass Index<br>(kg.m <sup>-2</sup> ) | $\bar{x}$ :<br>(S.D.): | 22.12<br>(3.53)  | 22.12<br>(3.29) |

Although it is commonly accepted that participation in physical conditioning is an important component in the reduction of body fat and consequently body mass (McArdle *et al.*, 1991), *Table IX* illustrates that there was no change in the mass, and therefore the body mass index, of the group as a whole over the ten-week period of work-hardening. As McArdle *et al.* (1991) however explain, a reduction in body mass as a result of physical conditioning is more evident in the obese or borderline obese, whilst the data above illustrates that on average the subjects were neither obese nor borderline obese prior to their participation in the work-hardening programme.

Indeed, the mean **BMI** value recorded for the group at the pre-conditioning test session is indicative of a group with lean muscular physiques. This is not surprising considering that physique is known to be strongly influenced by one's way of life, and the subjects in this study were selected on the basis of their involvement in occupational tasks of a physically demanding nature. This offers a possible explanation for the lack of change in the mean mass and **BMI** values for the group following their participation in the work-hardening

programme, as comparisons between the pre- and post-conditioning data could not be expected to be of the same magnitude had the subjects been a previously sedentary group of individuals.

Hard manual labour has been equated with strenuous physical exercise (Larson and Michelman, 1973) and according to Sharkey (1990), many studies have linked physical activity, and not physical fitness, to dramatic improvements in the heart and circulatory system. Considering then the already high level of physical activity that the subjects were involved in at their workplace prior to their participation in the work-hardening programme, a high level of cardiovascular and physical conditioning amongst the subjects should not, according to these authors, be unexpected.

However, as important as the above average level of physical fitness of the group as a whole is, the reality is that a substantial variation in physical condition existed amongst the subjects. This variation was conspicuous amongst all responses recorded at the pre- and post-conditioning test sessions (see *Tables IX - XVI*). The expansive range in ages and the varying years of involvement in physically demanding tasks of the subjects could be argued to be possible reasons for these substantial individual differences.

According to McArdle *et al.* (1991), it has been estimated that there is a decline in  $\text{VO}_2$  of approximately  $0.4\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$  per year, which is accompanied by a decline in maximal heart rate and maximum cardiac output as well as a decrease in muscle mass and therefore muscular strength. In addition, the results of the physical activity questionnaire conducted during the pre-conditioning laboratory testing revealed that 44% of the subjects participated

in some form of regular aerobic activity inclusive of activities such as running, rugby and soccer, whilst 28% were specifically involved in some kind of strength training programme. These facts would further affect the diversity of physical conditioning amongst the group.

The variation in the measures recorded at the pre- and post-conditioning test sessions thus compels one to consider intra-individual changes over the ten-week period rather than merely the average values in order to appreciate the effect of the work-hardening programme on the subjects.

Subsequently, although the pre-conditioning physique of the group provides a reasonable explanation for the lack of change in the mean mass of the group over the ten-week period, a closer look at individual changes in mass illustrates that a number of the heavier subjects in fact experienced a weight loss of between 1 and 5kg's with the heaviest subject losing 5kg's, whilst a few of the leaner subjects accrued between 1kg and 3kg. This offers another possible explanation for the lack of change in the mean mass of the group at the post-conditioning test session.

## **THE RESULTS OF PRE- AND POST-CONDITIONING TESTING**

This study sought to evaluate the holistic effect of a ten-week work-hardening programme on the physical work capacity of the subjects, as measured by cardiovascular, strength and perceptual responses. The results of the *in situ* task analyses and laboratory testing sessions will be dealt with separately.

## PRE- AND POST-CONDITIONING IN SITU TASK ANALYSES

Despite the diverse nature of the three industries, the twenty-five subjects were involved in similar occupational activities. These include the repetitive lifting, lowering, stacking and unstacking of merchandise in various size crates and packages. Subjects at the dairy and bottling company load and unload similar weight crates (10-31kg), whilst subjects at the wholesale warehouse unload and stack various forms of packaging (crates, boxes, and bags of produce weighing from 3-30kg). All subjects therefore spend the majority of their day lifting crates and/or boxes illustrating the need for the workers to have an above average level of back and arm strength.

The subjects typically work eight to nine hours per day where on average, they lift at a rate of 10 lifts per minute (SD 6.4) at regular intervals over their shift, five to six days per week. Due to task rotation within the dairy and the travelling nature of the job at the bottling company, the subjects do not actually spend their full shift lifting, but when they do, the intensity of activity is high. The highest lifting rate recorded was 19 lifts per minute.

*Table X* illustrates the length of the subjects' different workshifts, as well as the approximate time they spend lifting during the week, whilst *Table XI* provides a detailed explanation of the nature of the tasks at the three industries.

**Table X:** Duration of the overall workshift and average lifting hours per week per industry.

| INDUSTRY            |                         | WORKING HOURS PER WEEK | LIFTING HOURS PER WEEK    |
|---------------------|-------------------------|------------------------|---------------------------|
| Dairy               | Factory Despatch        | 52 - 53 hours          | 10 hours<br>20 - 25 hours |
| Wholesale Warehouse | Warehouse Receiving     | 50 hours               | 10 hours<br>20 - 25 hours |
| Bottling Company    | Warehouse Truck Helpers | 40 hours               | 20 hours<br>15 hours      |

**Table XI:** Nature of the tasks at the three industries.

| INDUSTRY             | NATURE OF THE TASKS   |
|----------------------|---|
| Dairy:               | <ol style="list-style-type: none"> <li>1) Pushing full crates along conveyor to despatch area,</li> <li>2) Lifting full crates from conveyor within despatch and stacking these,</li> <li>3) Loading stacked full crates onto push carts and wheeling these to areas of storage, and</li> <li>4) Loading and unloading the various crates to/from the delivery trucks.</li> </ol> |
| Wholesale Warehouse: | <ol style="list-style-type: none"> <li>1) Unloading various packages from delivery trucks to conveyor, from conveyor to palettes,</li> <li>2) Wheeling palettes up to the warehouse floor,</li> <li>3) Unloading palettes onto shelves and keeping shelves in order, and</li> <li>4) Attending to the needs of the customers by helping load and unload.</li> </ol>               |
| Bottling Company:    | <ol style="list-style-type: none"> <li>1) Loading beverage crates onto palettes which are then loaded onto the trucks by a hyster,</li> <li>2) Offloading crates from truck to push cart and wheeling to point of delivery,</li> <li>3) Unloading push cart in storage areas, and</li> <li>4) Retrieving empty bottles and loading these onto the truck.</li> </ol>               |

During their working day the subjects perform lifts, which range from just above floor level to heights well above their heads, and push and pull loads off and on conveyor belts, up and down stairs and ramps as well as in confined spaces. Such manoeuvres involve extended

reaches with their arms, low stooping positions and twisted body postures placing considerable strain on their musculoskeletal systems (see *Figures 7 - 9*). **liftRISK**, a risk assessment programme, was therefore used in order to conduct situational risk evaluations. Although these risk assessments were conducted following the pre-conditioning, laboratory testing, the results are included here in order to establish a clear idea as to the nature of the tasks performed in South African industry. These assessments took into account the inter-relatedness of the physical work capacities of the worker and the physical demands of the task. The **liftRISK** analyses of the **task inherent risk**, **predisposing operator risk** and **overall situational risk** notings of tasks regarded as typical to the industries are presented in *Figure 10*.



**Figure 7:** A worker loading merchandise from a delivery truck. Note the confined space in which he must work.



**Figure 8:** A worker unloading merchandise onto a pallet. Note how low he must stoop.



**Figure 9:** A worker loads bags of rice onto a conveyor. Note how he makes use of a twisting motion of his trunk in order to load the rice.

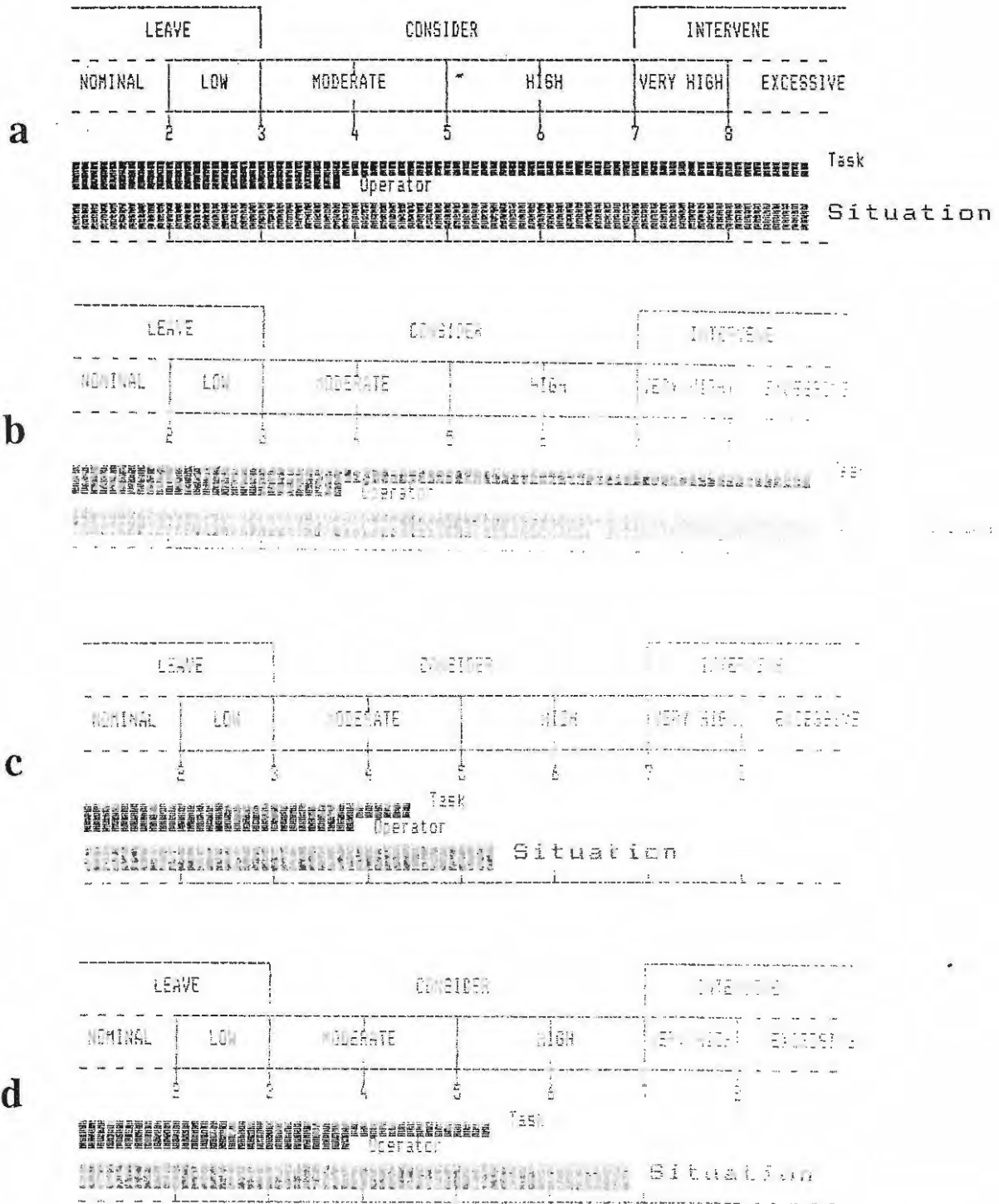


Figure 10: liftRISK analyses of the task, operator and overall situational risk ratings of four tasks regarded as typical of the nature of work at the three industries.

Despite the above average level of conditioning recorded for the subject group at the pre-conditioning laboratory testing sessions, substantial individual differences were also apparent. The author thus felt that rating the **operator** as being in average physical condition accommodated most of the subjects in the group. Therefore the **liftRISK** default values were used for the operator in all the above situations in order to identify task inherent and overall situational risk factors. The worker in *Figure 10* is thus considered as having an average physical working capacity and according to **liftRISK** this places him at a moderate risk for injury. An obvious intervention is to improve the worker's aerobic capacity and back and arm strength which is what the work-hardening programme aimed toward. Indeed, when these assessments were repeated with the worker recorded as having an **above average** physical work capacity, the **predisposing operator risk** was considered nominal.

*Figures 10a* and *b* above illustrate the task and overall situation rated as excessive. In situation *10a*, the horizontal reach of 109cm, which stresses the lower back and arms, and vertical stretch of 207cm, which places stress on the shoulders and arms, were rated "Off Scale". In situation *10b*, the vertical stretch of 213cm and lifting frequency of 19 lifts per minute, which is aerobically demanding, were regarded as "Off Scale". In both situations the mass of 30kg was considered too heavy especially considering the frequency at which the worker was lifting. In comparison, the tasks in *Figures 10c* and *d* were not rated as excessive, however the **task inherent risk** and **overall situational risk** were still rated "High" in both situations. In addition, but not apparent in situation *10c* is that the worker had to carry 6x30kg bottles of concentrate juice up six unusually high stairs in order for the concentrate juice to be emptied into a mixing keg, while in situation *10d* the worker lifted crates from just above floor height to 172cm above the floor in a very confined space and

in very cold environmental conditions (see *Figure 11*).



**Figure 11:** Situation *10d*. Note how low the conveyor belt enters into the despatch area and how high the crates are stacked. Also note the confined area in which the worker must perform his task.

Intervention strategies proposed by the **liftRISK** programme include reducing the vertical stretch, specifically in situation *10a* and *b*, the horizontal reach and mass in all the situations presented in *Figure 10*, and the frequency of the lift, particularly in situation *10b*. Indeed, ergonomic redesign of the task demands would appear critical in the above situations. A horizontal reach of 109cm is especially excessive when one takes into account that the mass

of the object was 30kg. **liftRISK** suggests that at this mass, an acceptable reach factor should not be further than 40cm. Vertical stretches of 207cm and 213cm are also irrational considering that the average height of the worker was 1.68m. This situation therefore results in the worker having to almost throw the crate to the required height necessitating a jerking movement which can often result in a musculoskeletal injury like low-back pain. **liftRISK** therefore proposes that when workers are lifting these kind of masses that the vertical stretch not exceed 156cm.

Unfortunately management is not always agreeable to redesign in the work station as this is often a costly procedure. Nevertheless, the need for ergonomic intervention cannot be ignored. However, the use of the work-hardening programme to not only improve the workers' physical work capacities but also educate the workers' in effective body mechanics and safe working postures and techniques may help in the reduction of musculoskeletal injuries at these workplaces. During the work-hardening programme the subjects were therefore educated in good coupling methods and on how to keep the load close to their body. In order to complement these techniques, strengthening exercises concentrated on back and arm strength. The workers were also shown how to use their whole body to execute a lift and move their feet instead of twisting their trunks.

During the *in situ* task analyses measures of **peak** and **average working** heart rate as well as ratings of perceived exertion were recorded.

## Cardiovascular Responses

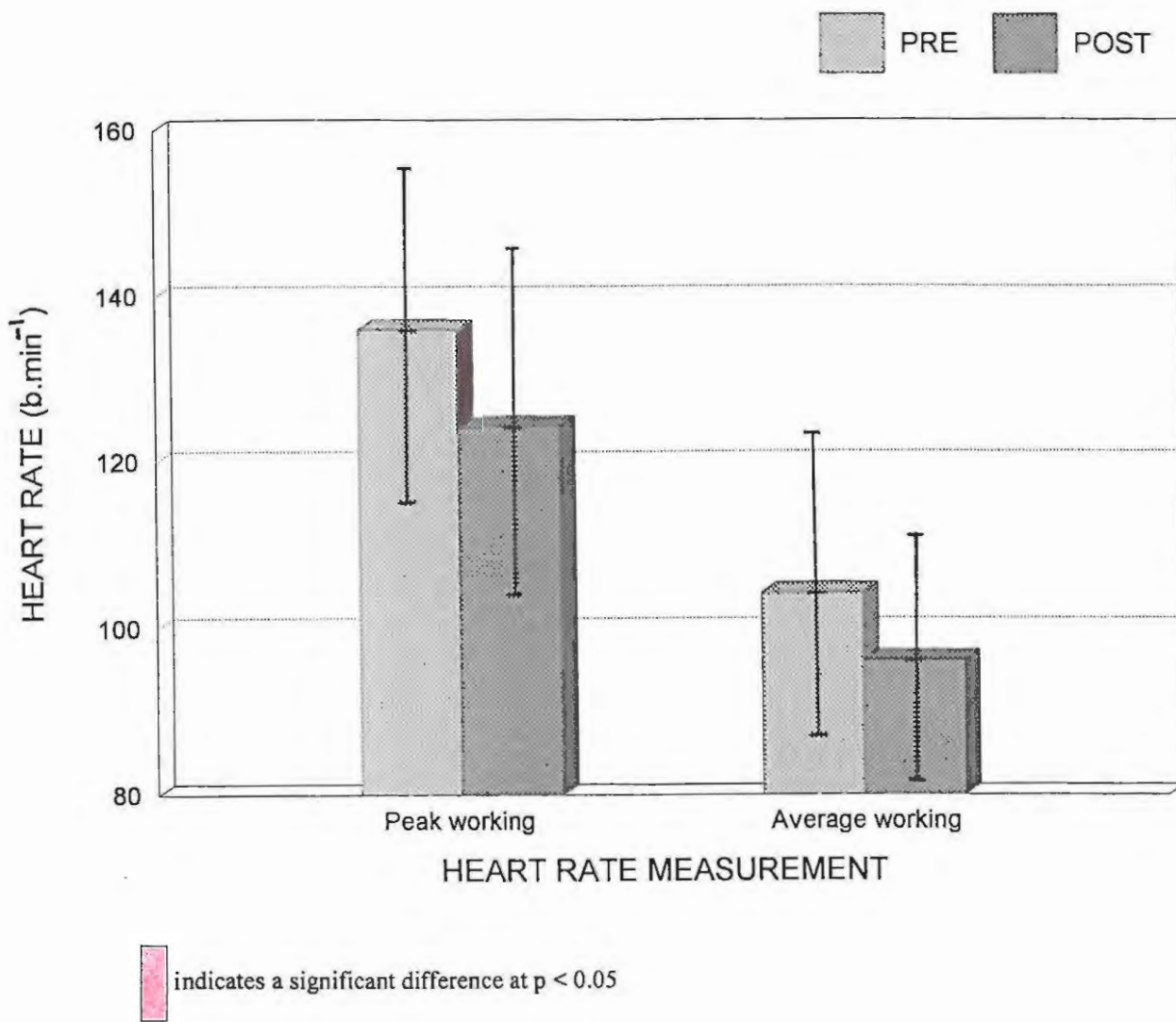
### Working Heart Rate

One of the training effects of regular participation in physical activity is a decrease in working heart rate. Saltin (1990) explains that this reduction in working heart rate is directly as a result of an increased stroke volume and cardiac output in the trained individual.

The effect of the work-hardening programme on **peak** and **average working** heart rates is presented in *Table XII* and *Figure 12*. These illustrate that there was a nominal reduction in the group's **average working** heart rate measures following ten-weeks participation in the conditioning programme with a statistically significant reduction in **peak working** heart rate.

Considering the intensity of physical activity observed at the industries, the mean **peak working** heart rate measure recorded from the pre-conditioning *in situ* task analyses sessions was not unduly high. This moderate working heart rate may be attributed to the healthy level of cardiovascular conditioning recorded for the group as a whole prior to their participation in the conditioning programme. The fact that participation in the work-hardening programme was successful in reducing this **peak working** heart rate measure even further, is therefore particularly significant.

The mean **average working** heart rate measure recorded from the pre-conditioning *in situ* task analyses was relatively low. This however, is accredited to, not only the high level of cardiovascular conditioning evident amongst the group, but also to the fact that the subjects did not lift consistently over the thirty minute assessment period, especially in the dairy and



**Figure 12:** Peak and average working heart rate measured at the pre- and post-conditioning *in situ* task analyses.

wholesale warehouse. The phases of inactivity within this thirty minute period resulted in a drop in the **working** heart rate thus affecting the overall **average working** heart rate. One could thus argue that the lack of significant differences between the measures of **average working** heart rate are not surprising and that the measures of **peak working** heart rate are

more typical of the pre- and post-cardiovascular conditioning of the subject group. The significant reduction in **peak working** heart rate following the ten-week period of work-hardening may therefore be considered more representative of the effect of the work-hardening programme on the cardiovascular conditioning of the group.

**Table XII:** Peak and average working heart rates as well ratings of perceived exertion recorded at the pre- and post-conditioning *in situ* task analyses.

| DATA   |                        | CONDITION         |                     |
|--|------------------------|-------------------|---------------------|
|  |                        | PRE               | POST                |
| Peak working heart rate<br>(b.min <sup>-1</sup> )    | $\bar{x}$ :<br>(S.D.): | 136.08<br>(19.07) | 124.28 *<br>(19.63) |
| Average working heart rate<br>(b.min <sup>-1</sup> ) | $\bar{x}$ :<br>(S.D.): | 104.2<br>(17.43)  | 96.12<br>(14.99)    |
| Rating of perceived exertion                         | $\bar{x}$ :<br>(S.D.): | 10<br>(2.56)      | 10<br>(2.13)        |

\* indicates a significant difference at  $p < 0.05$

### Perceptual Responses

The subjects' ratings of perceived exertion were included in the task analyses in order to obtain a tangible assessment of the subjects' perceptions of the physical demands of their tasks.

*Table XII* depicts that using the Borg RPE scale, the subjects' ratings revealed no difference in their perceptions of the physical demands of their jobs before and after their participation in the occupation-specific work-hardening programme. *Table XII* also illustrates the low

ratings of perceived exertion recorded. Considering the physically demanding nature of the activities observed in the industries, it seems improbable that the workers could perceive their tasks to be so effortless. A possible reason for these low ratings and the lack of change in the ratings following the ten-week period of work-hardening may be as a result of the language problem, resulting in a conceptual misunderstanding of the RPE scale. Contrary to the ACSM's (1991) findings that the RPE scale is a reproducible measure of exertion within a wide variety of individuals regardless of cultural origin, it would appear that in the present project the language barrier proved to be an obstacle in the explanation and interpretation of this scale. Unfortunately, it is therefore difficult to speculate how the subjects interpreted the ratings and what their ratings actually meant in terms of the study.

Considering the lack of differences between the pre- and post-perceptual responses it is interesting to note that during the pre-conditioning *in situ* analysis of each of the subject's tasks, as well as from information gained out of a medical history questionnaire presented to the subjects during the pre-conditioning laboratory testing, 68% of the subjects stated that they experienced lower back discomfort and 56% stated that they also experienced upper back and neck discomfort at the end of their day as a result of the physical demands of their jobs. However, substantially fewer subjects complained of discomfort following their participation in the work-hardening programme as only 44% of the subjects stated that they still experienced lower back discomfort, and 40% that they experienced upper back and neck discomfort at the end of their day. In addition, a number of these subjects stated that these discomforts were not as painful as they had been prior to their participation in the conditioning programme. It would therefore appear that the subjects did in fact perceive some improvement in their physical work capacity as a result of the ten-week period of work-

hardening.

## PRE- AND POST-CONDITIONING LABORATORY DATA COLLECTION

These laboratory testing sessions served to document any improvements in the subjects' physical work capacity as measured by specific cardiovascular and strength tests as well as ratings of perceived exertion, following the ten-week period of work-hardening.

### Cardiovascular Responses

The cardiovascular responses recorded at the pre- and post-conditioning test sessions appear in *Table XIII*. Apparent from this table as well as *Figures 13* and *14*, is the reduction in the groups' heart rate and blood pressure measures following their involvement in the work-hardening programme.

### Heart Rate Responses

It is generally accepted that as a result of regular participation in physical activity, resting as well as working heart rate responses to any given submaximal level of exercise, decrease. In addition, heart rate returns more rapidly to normal after participation in physical activity (Fisher and Jensen, 1990; Saltin, 1990).

#### Resting/Reference Heart Rate

*Figure 13* depicts the nominal reduction in the mean reference heart rate value for the subject group following their participation in the ten-week work-hardening programme.

The high variability within the data collected, together with the previously above average level of aerobic fitness of the group prior to conditioning provides an understandable reason for the lack of significant differences recorded in these heart rate measures.

**Table XIII:** Cardiovascular responses collected at the pre- and post-conditioning laboratory test sessions.

| DATA   | CONDITION             |                         |
|--|-----------------------|-------------------------|
|  | PRE                   | POST                    |
| Reference heart rate (b.min <sup>-1</sup> )<br><div style="text-align: right;"> <math>\bar{x}</math>:<br/>           (S.D.):         </div>                                  | 68.92<br>(11.48)      | 64.64<br>(9.34)         |
| Working heart rate (Cybex:60°.sec <sup>-1</sup> )<br>(b.min <sup>-1</sup> )<br><div style="text-align: right;"> <math>\bar{x}</math>:<br/>           (S.D.):         </div>  | 124.48<br>(22.79)     | 117.64<br>(22.54)       |
| Working heart rate (Cybex:120°.sec <sup>-1</sup> )<br>(b.min <sup>-1</sup> )<br><div style="text-align: right;"> <math>\bar{x}</math>:<br/>           (S.D.):         </div> | 127.52<br>(23.52)     | 110.04 *<br>(23.21)     |
| Recovery heart rate (HST min 1) <sup>#</sup><br>(b.min <sup>-1</sup> )<br><div style="text-align: right;"> <math>\bar{x}</math>:<br/>           (S.D.):         </div>       | 111.68<br>(20.78)     | 108.36<br>(20.11)       |
| Resting blood pressure (mmHg)<br><div style="text-align: right;"> <math>\bar{x}</math>:<br/>           (S.D.):         </div>  | 130/90<br>(15.9/14.4) | 114/77 *<br>(13.2/10.6) |

# Recovery heart rate (HST min 1): a measure of recovery heart rate after the first minute of recovery at completion of the Harvard Step Test.

\* indicates a significant difference at  $p < 0.05$

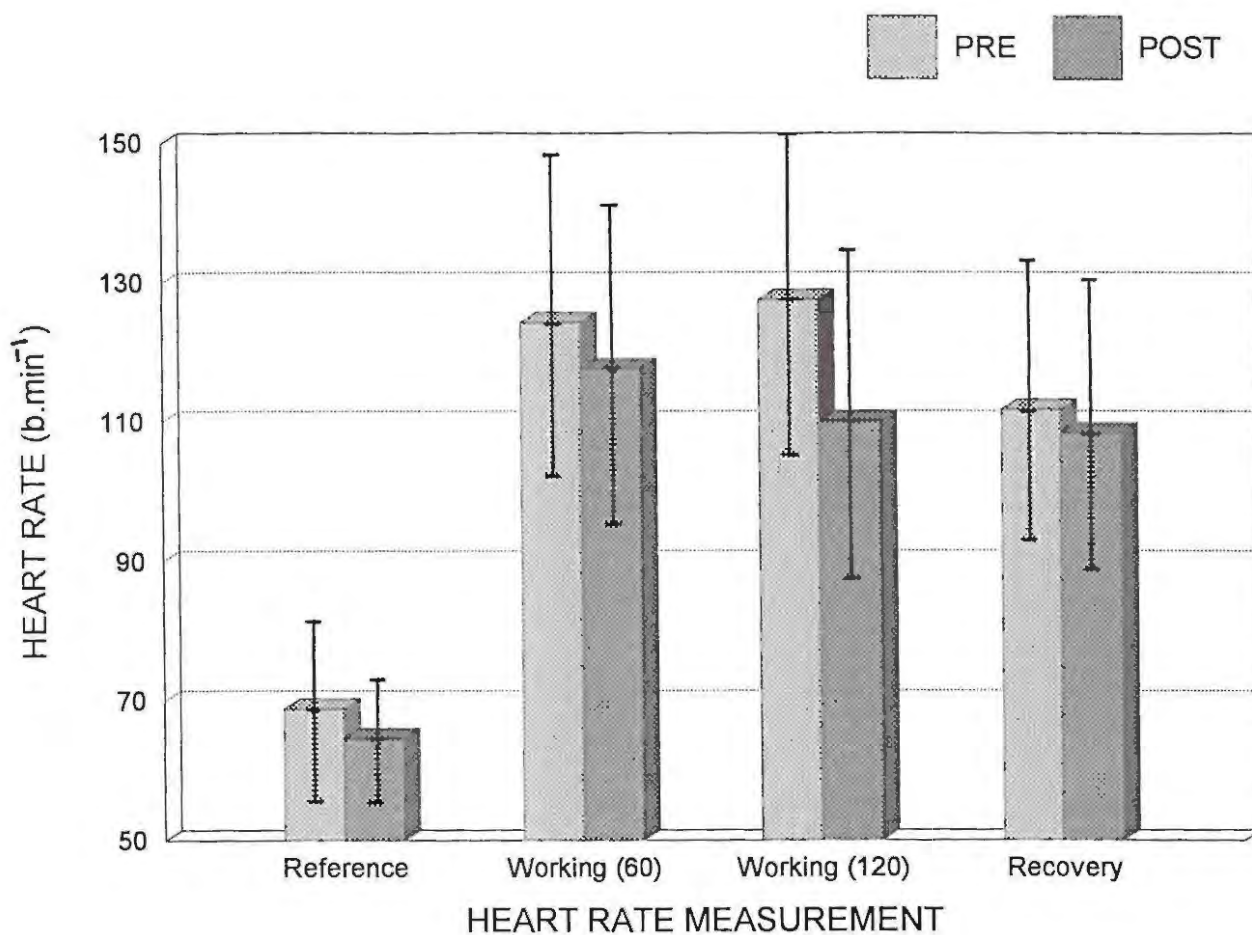
### Working Heart Rate

Two working heart rates were recorded during the isokinetic strength assessments on the CYBEX 6000. These measures were made immediately following trunk strength testing at a velocity of 60 and 120°.sec<sup>-1</sup>. Analysis of the data revealed a general reduction in the mean working heart rates following the ten-week period of work-hardening. However, it was only when subjects were working at the higher velocity (120°.sec<sup>-1</sup>) that there was a significant

drop in **working** heart rate from 128b.min<sup>-1</sup> to 110b.min<sup>-1</sup>. This significant difference is clearly evident in *Figure 13*.

The significant reduction in the mean **working** heart rate at a velocity of 120°.sec<sup>-1</sup> is important to note, particularly considering that there was also an increase in the relative strength measures at this velocity at the post-conditioning test session. It would appear that the effect of the workload on their cardiovascular system at this velocity of strength testing was significantly reduced at the post-conditioning test session. As McArdle *et al.* (1991) explain, less regional blood flow is required to meet the muscles' oxygen needs in trained individuals which means a relatively lower cardiac output and therefore working heart rate.

Recognizably, the drop in heart rate could be the result of the subjects feeling less apprehensive at the second test session. However, *Figure 13* illustrates how at the pre-conditioning test session the mean **working** heart rate recorded at a velocity of 60°.sec<sup>-1</sup> was moderately lower than that recorded at a velocity of 120°.sec<sup>-1</sup>, whilst at the post-conditioning session the mean **working** heart rate recorded at the faster velocity was substantially lower than that recorded at the slower velocity. If the significant drop in working heart rate was attributable to the subjects feeling less apprehensive then one would expect to see a similar reduction in both working heart rates (60 and 120°.sec<sup>-1</sup>). One can therefore assume the significant reduction in working heart rate at 120°.sec<sup>-1</sup> to be as a result of the subjects' involvement in the work-hardening programme.



**Figure 13:** Heart rate responses recorded at the pre- and post-conditioning laboratory test sessions.

### Recovery Heart Rate

Heart rate was also recorded during the subjects' execution of the Harvard Step Test. The purpose of this test was to use measurement of recovery heart rate from a standardized exercise bout as a rough means of assessing cardiovascular efficiency.

As is evident from *Figure 13*, there was no difference between the pre- and post-conditioning mean recovery heart rate. This measure was recorded at one minute of recovery after the subjects had completed the Harvard Step Test. These recovery values were further used in equations (see *Chapter 3*) in order to rate the subjects' aerobic conditioning according to norms for the Harvard Step Test (see *Table V*). The average values are presented in *Table XIV*. As previously mentioned, as well as obvious from this table is that the subjects already demonstrated an above average level of aerobic fitness prior to their participation in the work-hardening programme.

**Table XIV:** Results of the Harvard Step Test.

|                                |                                   | CONDITION                  |                               |
|--------------------------------|-----------------------------------|----------------------------|-------------------------------|
|                                |                                   | PRE                        | POST                          |
| Harvard Step Test duration (s) | $\bar{x}$ :<br>(S.D.):            | 259.88<br>(70.23)          | 280<br>(53.15)                |
| Harvard Step Test score        | $\bar{x}$ :<br>(S.D.):<br>Rating: | 91<br>(33.99)<br>Very Good | 94.16<br>(23.51)<br>Very Good |

Although aerobic conditioning is known to reduce the heart's recovery time after participation in physical activity (Fisher and Jensen, 1990; Sharkey, 1990), such a reduction is more substantial when dealing with previously unconditioned individuals. As McArdle *et al.* (1991) recognise, training improvements depend largely on one's initial level of conditioning and if this is high then one can expect relatively little improvement. This offers a possible explanation for the nominal decreases in the subject group's mean reference, working (Cybex: 60°.sec<sup>-1</sup>) and recovery heart rates (*Table XIII*), as well as the negligible

improvements in mean **duration** and mean score (*Table XIV*), following participation in the ten-week work-hardening programme.

The fact that there was a considerable reduction in the variability within the measures at the post-conditioning test session would appear to indicate that as a result of the work-hardening programme the diversity of cardiovascular conditioning evident amongst the subject group decreased. Indeed, some of the subjects experienced considerable reductions in the heart rate measures presented in *Table XIII* following their participation in the conditioning programme which would seem to indicate that these subjects experienced an improvement in their level of physical conditioning. Admittedly it is impossible to conclude whether these intra-individual differences were as a result of the conditioning programme only or that the subjects may have been more at ease with the heart rate monitor at the post-conditioning test session. Nonetheless, to illustrate these substantial intra-individual differences a few individual responses have been highlighted; a drop in **reference** heart rate of up to  $27\text{b}\cdot\text{min}^{-1}$ , a reduction in **working** heart rate (Cybex:  $60^{\circ}\cdot\text{sec}^{-1}$ ) of  $46\text{b}\cdot\text{min}^{-1}$  as well as a faster **recovery** rate by  $54\text{b}\cdot\text{min}^{-1}$ .

The considerable intra-individual improvements in the Harvard Step Test's **duration** and **score** are however more tolerant to a theory of improved aerobic fitness following participation in a conditioning programme. These individual improvements include a 100% increase in **duration** (from 75s or 150s to 150s or 300s respectively) and an increase of up to 55 in the HST **score**.

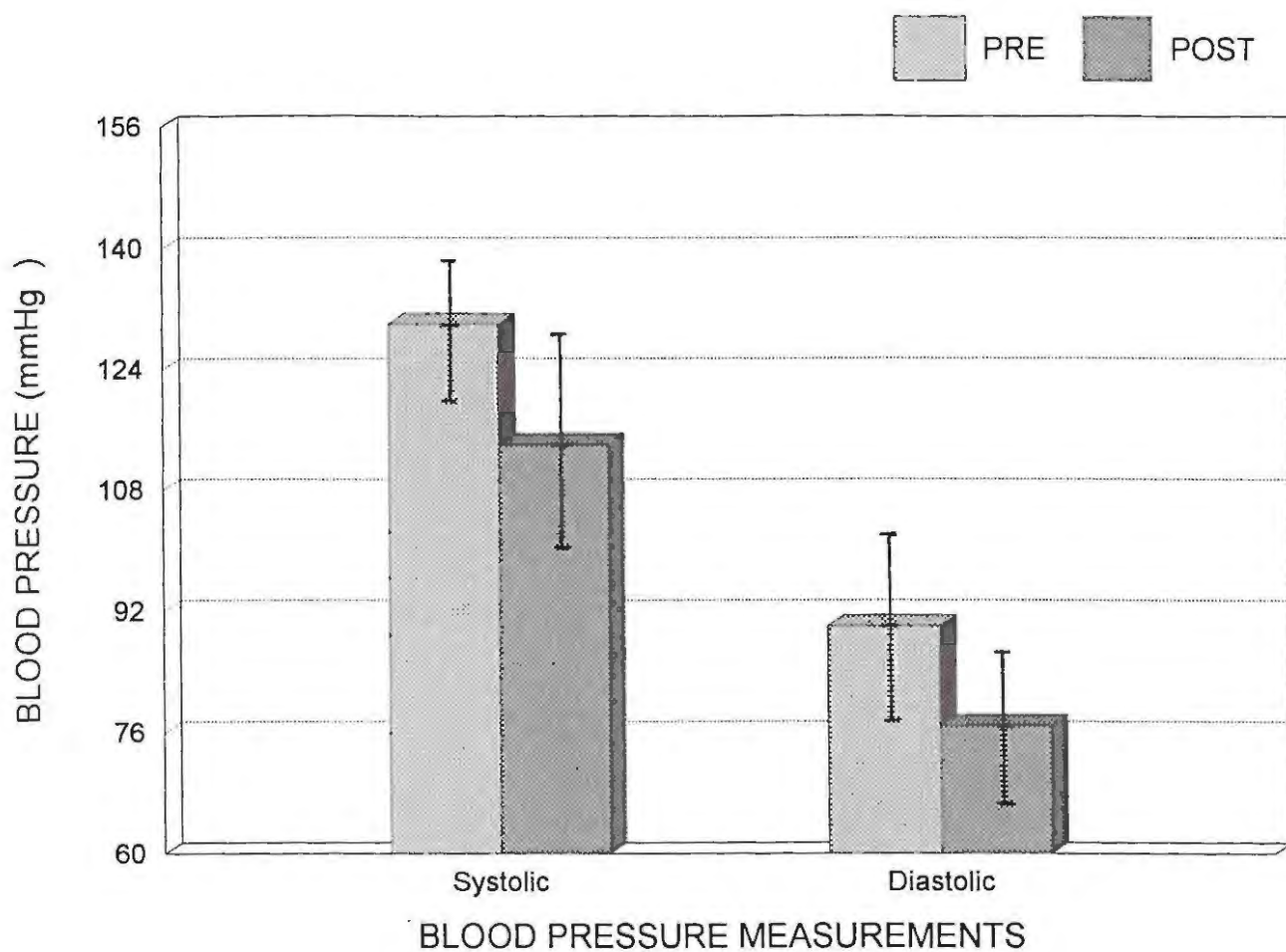
A reduction in the diversity of physical conditioning present amongst the subject group will

clearly be beneficial within the workplace as it would surely allow a more consistent rate of work throughout the industry.

### **Blood Pressure**

The American College of Sports Medicine (1991) states that blood pressure at rest or at any given percent of  $VO_2$ max may be reduced moderately in healthy individuals and more substantially in hypertensive individuals following physical conditioning.

The blood pressure results, which appear in *Table XIII* and *Figure 14*, illustrate that there was a significant reduction in both systolic and diastolic blood pressure at rest. The reason for this may be twofold. Firstly, most of the subjects experienced a moderate drop in blood pressure which could be attributed to their participation in the work-hardening programme. Secondly, in spite of the fact that the mean blood pressure value recorded at the pre-testing session was not indicative of a group of hypertensive individuals, it is apparent from the relatively large standard deviations that a number of the subjects may well have been hypertensive before their participation in the ten-week work-hardening programme. As the ACSM (1991) explain, if one is hypertensive one can expect substantial reductions in blood pressure following physical conditioning. The significant differences in blood pressure are in fact as a result of the substantial decrease in both systolic and diastolic blood pressure in three hypertensive subjects following the ten-week period of work-hardening.



indicates a significant difference at  $p < 0.05$

**Figure 14:** Resting blood pressure measures recorded at the pre- and post-conditioning laboratory test session.

#### STRENGTH MEASURES

Developing strength, power and endurance of worker's musculature is an important factor in reducing not only the frequency but also the severity of injuries because well conditioned

muscles increase body control and thus the ability to minimize the likelihood of injury. Considering the earlier **liftRISK** ratings for the tasks considered typical to the industries, it would seem essential that the workers demonstrate an above average musculoskeletal performance in order to reduce the occurrence of occupational injuries in such physically demanding work environments.

The **CYBEX 6000**'s detailed numerical analyses of the subjects' musculoskeletal status provides both absolute and relative strength data. However, as a result of the substantial diversity in physique apparent amongst the subjects, relative strength data were used in the analysis of strength testing.

### **Grip Strength**

*Table XV* demonstrates that analysis of the relative grip strength data revealed a significant improvement between the pre- and post-conditioning measures of relative **peak torque**, **total work** and **average power**. Indeed, the absolute values show that hand grip **peak torque** increased from 38Nm to 44Nm, **total work** from 13J to 16J and **average power** from 9W to 12W, indicating a statistically significant improvement in the subjects' abilities to produce substantially greater force and therefore generate more work and a larger power output during their hand grip performance following the period of work-hardening. The significant differences are illustrated in *Figure 15*.

**Table XV:** Relative grip strength measures recorded at the pre-and post-conditioning laboratory test sessions.

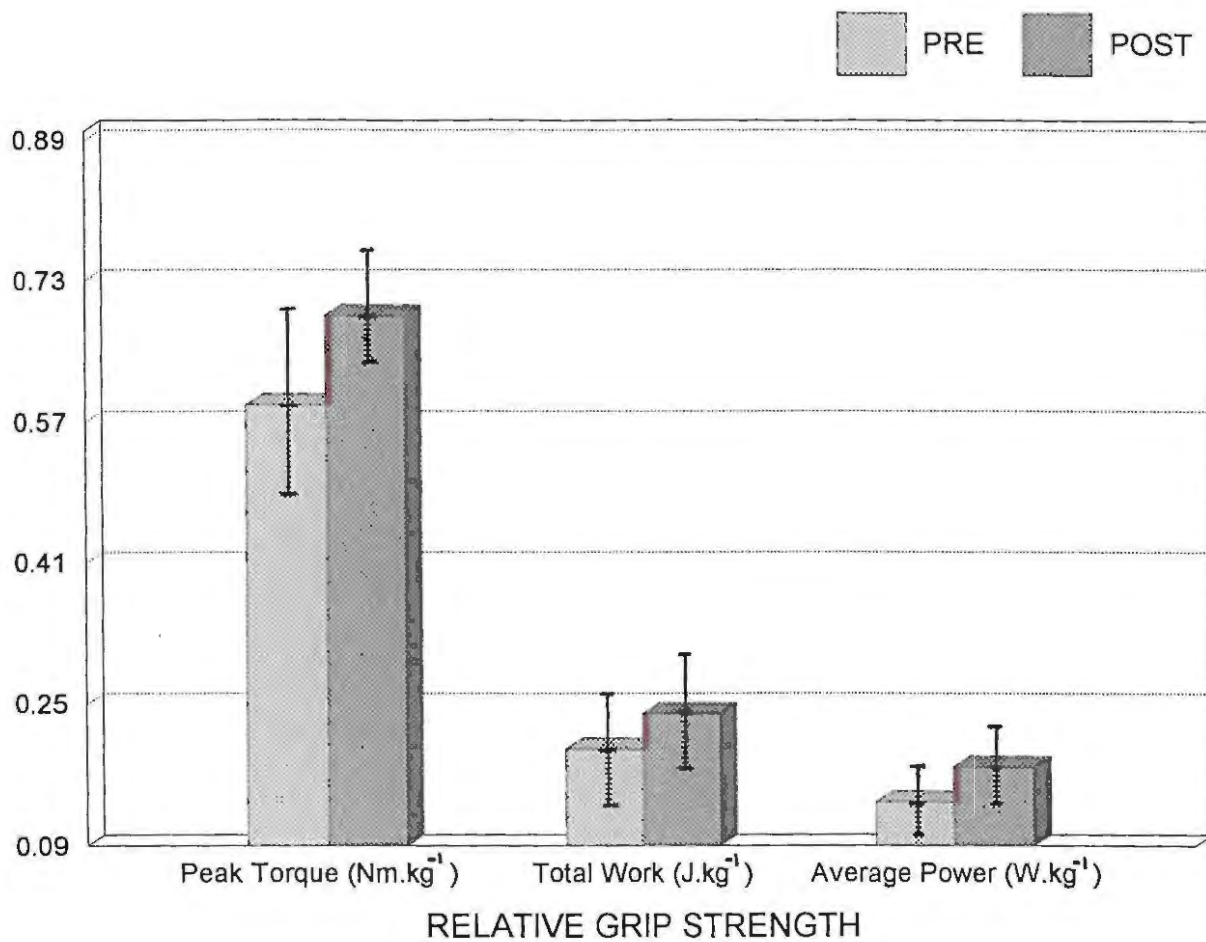
| CONCENTRIC CLOSED GRIP:             |             | CONDITION |        |
|-------------------------------------|-------------|-----------|--------|
|                                     |             | PRE       | POST   |
| Peak torque (Nm.kg <sup>-1</sup> )  | $\bar{x}$ : | 0.59      | 0.69 * |
|                                     | (S.D.):     | (0.10)    | (0.09) |
| Total work (J.kg <sup>-1</sup> )    | $\bar{x}$ : | 0.20      | 0.24 * |
|                                     | (S.D.):     | (0.05)    | (0.06) |
| Average power (W.kg <sup>-1</sup> ) | $\bar{x}$ : | 0.14      | 0.18 * |
|                                     | (S.D.):     | (0.04)    | (0.04) |

\* indicates a significant difference at  $p < 0.05$

It is the concept of work-hardening to integrate the actual components of the workers' occupational tasks into the conditioning programme. As such, the present study made use of crates during the job-specific phase of the conditioning programme. Naturally lifting the crates requires a gripping action which was emphasized in the programme and which could have played a major role in the significant increase in strength following the subjects' period of work-hardening.

### Trunk Strength

Examination of the relative and absolute trunk strength data revealed a nominal improvement in all strength measures of the subjects' trunk musculature following their participation in the ten-week work-hardening programme. *Table XVI* demonstrates that further analysis of these data revealed that a number of the improvements were statistically significant.



indicates a significant difference at  $p < 0.05$

**Figure 15:** Relative grip strength data recorded at the pre- and post-conditioning laboratory test sessions.

*Table XVI* also illustrates the substantial variation present amongst the strength capabilities of the workers. These individual differences are thought to be primarily as a result of the difference in years the subjects have spent involved in physically demanding manual labour.

**Table XVI:** Relative trunk strength measures recorded at the pre- and post-conditioning laboratory test sessions.

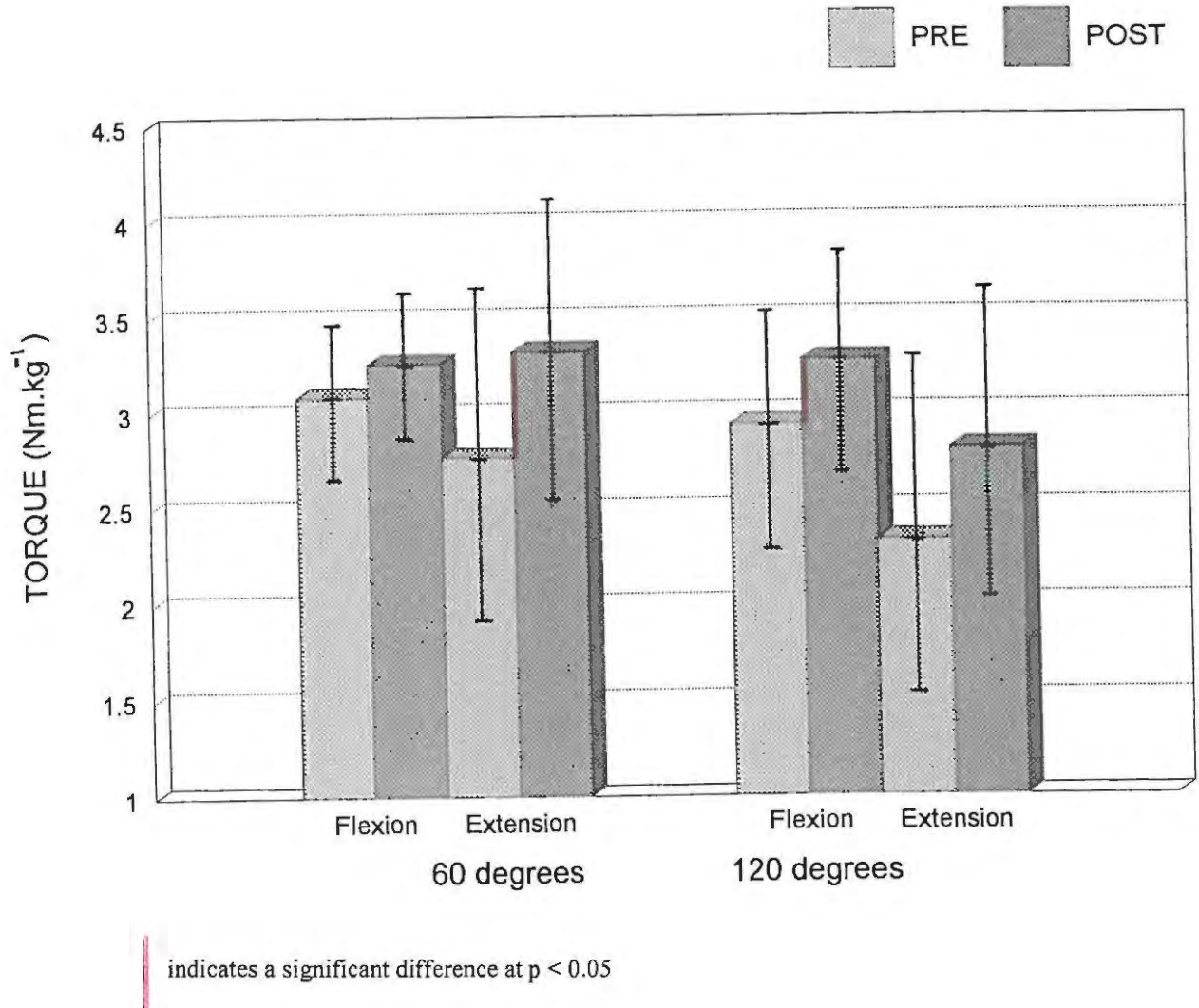
|                                     |             | CONDITION             |        |                        |        |
|-------------------------------------|-------------|-----------------------|--------|------------------------|--------|
|                                     |             | 60°.sec <sup>-1</sup> |        | 120°.sec <sup>-1</sup> |        |
| CONCENTRIC TRUNK FLEXORS            |             | PRE                   | POST   | PRE                    | POST   |
| Peak torque (Nm.kg <sup>-1</sup> )  | $\bar{x}$ : | 3.09                  | 3.26   | 2.94                   | 3.27 * |
|                                     | (S.D.):     | (0.35)                | (0.40) | (0.55)                 | (0.54) |
| Total work (J.kg <sup>-1</sup> )    | $\bar{x}$ : | 4.05                  | 4.42 * | 3.60                   | 3.91   |
|                                     | (S.D.):     | (0.71)                | (0.55) | (0.85)                 | (0.65) |
| Average power (W.kg <sup>-1</sup> ) | $\bar{x}$ : | 1.96                  | 2.31 * | 3.60                   | 3.95   |
|                                     | (S.D.):     | (0.42)                | (0.37) | (0.95)                 | (0.79) |
| CONCENTRIC TRUNK EXTENSORS          |             | PRE                   | POST   | PRE                    | POST   |
| Peak torque (Nm.kg <sup>-1</sup> )  | $\bar{x}$ : | 2.77                  | 3.32 * | 2.33                   | 2.81   |
|                                     | (S.D.):     | (0.87)                | (0.79) | (0.92)                 | (0.81) |
| Total work (J.kg <sup>-1</sup> )    | $\bar{x}$ : | 3.36                  | 3.99 * | 2.52                   | 3.13 * |
|                                     | (S.D.):     | (1.04)                | (1.00) | (1.08)                 | (1.04) |
| Average power (W.kg <sup>-1</sup> ) | $\bar{x}$ : | 1.63                  | 2.08 * | 2.47                   | 3.10   |
|                                     | (S.D.):     | (0.63)                | (0.61) | (1.14)                 | (1.10) |

\* indicates a significant difference at  $p < 0.05$

Figure 16 illustrates the improvement in the mean **peak torque** measures of the flexors and extensors of the trunk following the subjects' ten-week period of work-hardening. According to Perrin (1993), concentric peak torque values tend to decrease with increases in test velocity. Figure 16 illustrates how this was true for trunk extension but that the trunk flexion values recorded during the testing velocities of 60 and 120°.sec<sup>-1</sup> were in fact the same at the post-conditioning test session. This may be attributed to the fact that the strengthening exercise for the trunk flexors i.e. the sit-up, was performed at a faster velocity toward the end of the ten-week period. In such a manner progressive overload was achieved not through an increase in resistance but an increase in velocity.

Examination of the data revealed that the improvement in the peak torque of the trunk

extensors from 179Nm to 212Nm tested at a velocity of 60°.sec<sup>-1</sup> and the improvement in the peak torque of the trunk flexors from 198Nm to 209Nm tested at a velocity of 120°.sec<sup>-1</sup> were significant (p < 0.05). These differences are clearly illustrated in the figure below.



**Figure 16:** Relative peak torque measures recorded at the pre- and post-conditioning laboratory test sessions during strength testing on the CYBEX 6000.

Also evident in *Figure 16* is the change in the subjects' sagittal dynamic muscle balance following their participation in the work-hardening programme. The extensor/flexor ratios are presented in *Table XVII*.

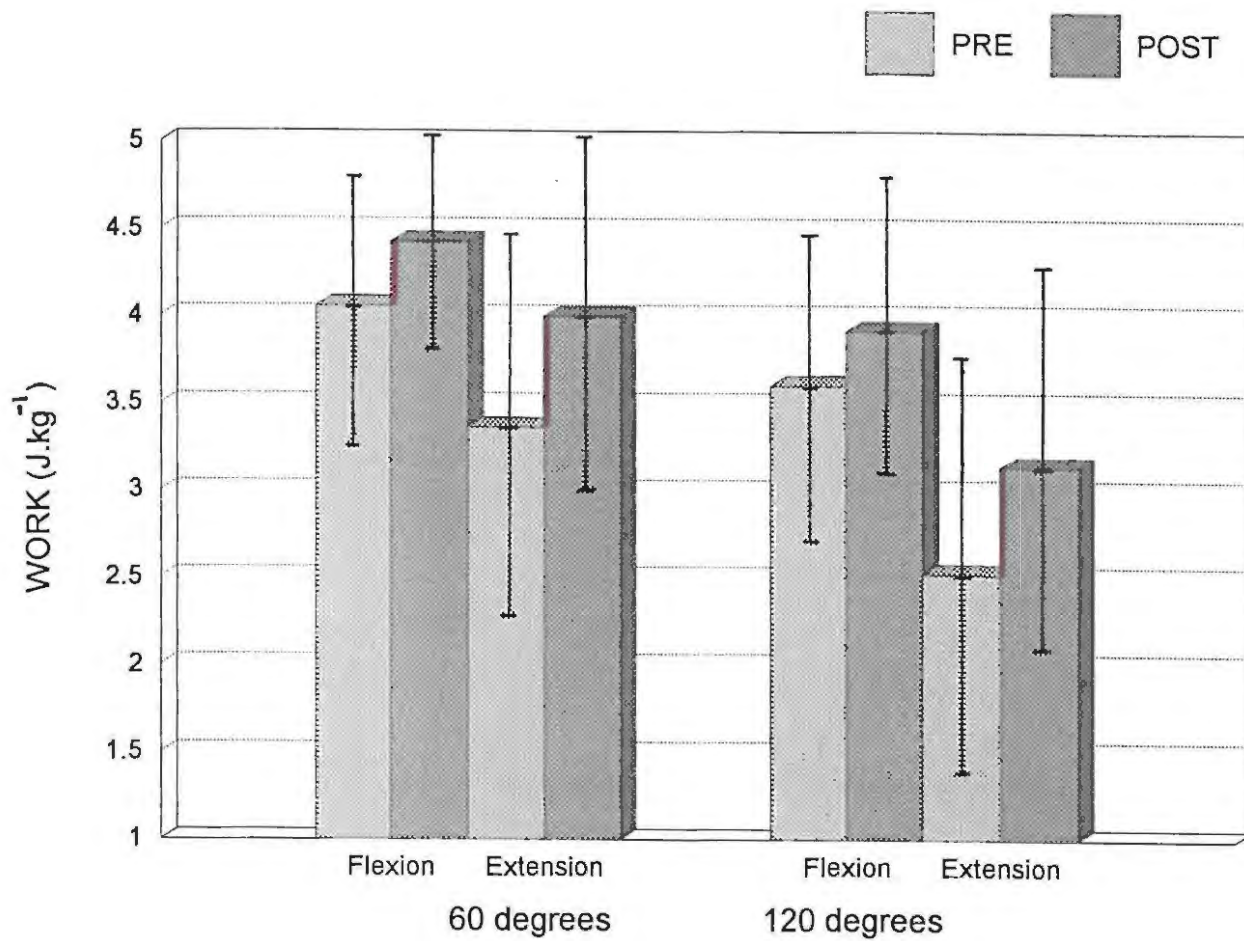
**Table XVII:** Trunk extensor/flexor ratios recorded at the pre- and post-conditioning laboratory test sessions.

| EXTENSOR/FLEXOR RATIO | CONDITION             |      |                        |      |
|-----------------------|-----------------------|------|------------------------|------|
|                       | 60°.SEC <sup>-1</sup> |      | 120°.sec <sup>-1</sup> |      |
|                       | PRE                   | POST | PRE                    | POST |
| Peak torque           | 0.89                  | 1.01 | 0.79                   | 0.85 |
| Total work            | 0.82                  | 0.90 | 0.70                   | 0.80 |
| Average power         | 0.81                  | 0.91 | 0.69                   | 0.78 |

The ratios in *Table XVII* demonstrate how there was an improvement in trunk extensor strength relative to trunk flexor strength. In addition, at the post-conditioning test session, when tested at a velocity of 60°.sec<sup>-1</sup> the **peak torque** produced by the trunk extensors exceeded that produced by the trunk flexors. These factors are of particular relevance considering that the trunk extensors are the primary muscles involved in the execution of the subjects' daily lifting activities.

The improvements reflected in the measures of **peak torque** were also evident amongst the mean **total work** measures recorded during the isokinetic trunk strength testing. These measures refer to the total amount of **force** being generated by the trunk musculature. *Figure 17* illustrates these improvements and it is also evident that at the higher velocity measures

of total work decreased.

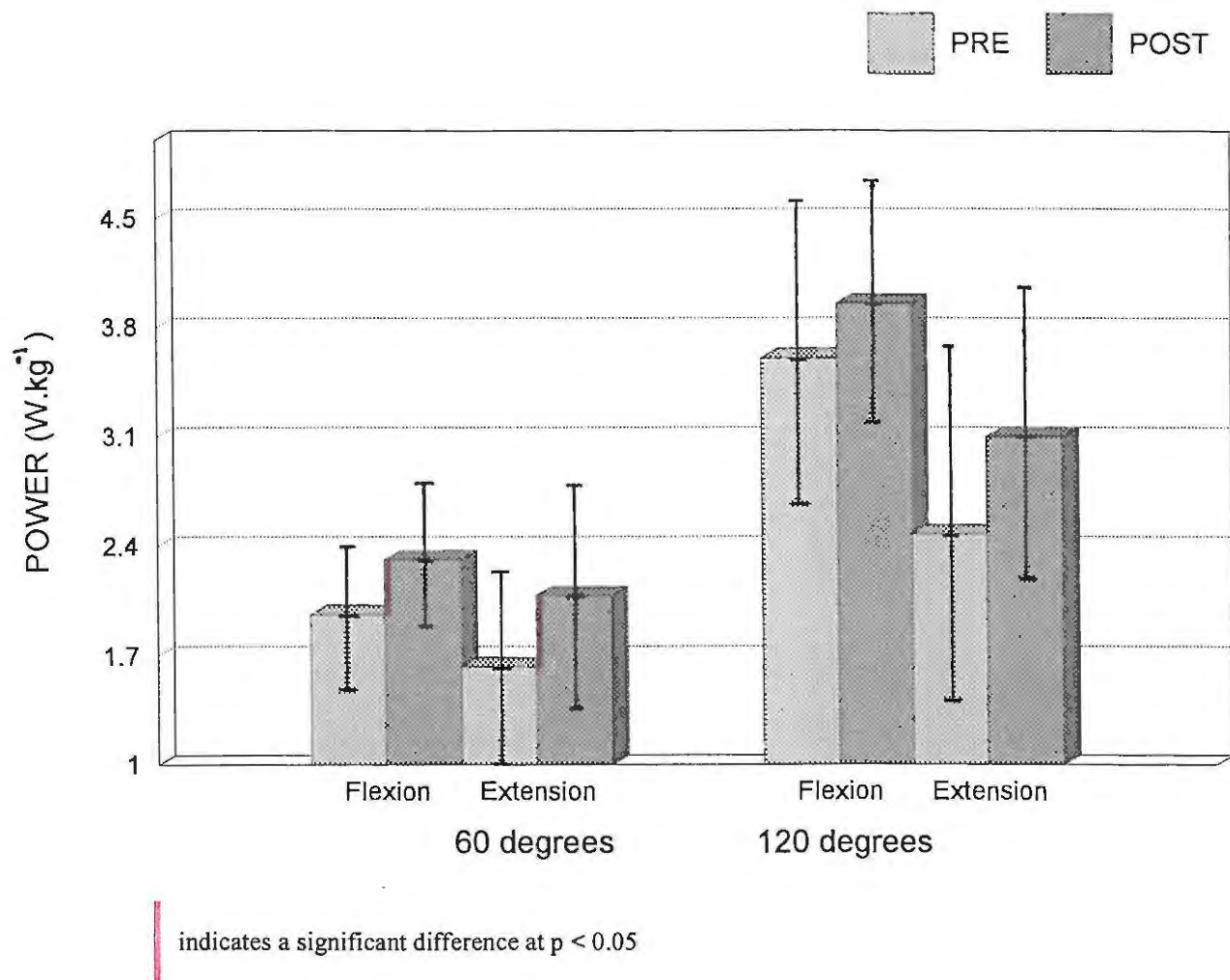


indicates a significant difference at  $p < 0.05$

**Figure 17:** Relative total work measures recorded at the pre- and post-conditioning laboratory test sessions during strength testing on the **CYBEX 6000**.

The post-conditioning improvement in the flexor and extensor total work measures, from 262J to 283J and from 214J to 257J respectively, recorded at a testing velocity of  $60^{\circ}.\text{sec}^{-1}$ ,

as well as the improvement in the extensor **total work** measure from 163J to 201J recorded at a testing velocity of  $120^{\circ}.\text{sec}^{-1}$ , were statistically significant. These significant differences were an improvement of approximately  $0.5\text{Nm}.\text{kg}^{-1}$ .



**Figure 18:** Relative average power measures recorded at the pre- and post-conditioning laboratory test sessions during strength testing on the CYBEX 6000.

The differences between the pre- and post-conditioning measures of **average power** of the subjects' trunk musculature are illustrated in *Figure 18*. Measures of flexion and extension recorded at a velocity of  $60^{\circ}.\text{sec}^{-1}$  improved significantly over the ten-week period of work hardening. This was an increase in power of 22 watts during trunk flexion and 34 watts during trunk extension, indicating the previously mentioned greater strength improvement of the trunk extensors.

However, in comparison to the previous two figures, *Figure 18* demonstrates that the **average power** measures increased with an increase in velocity. This is merely a function of time as testing at  $120^{\circ}.\text{sec}^{-1}$  obviously occurred over a shorter time period than did testing at  $60^{\circ}.\text{sec}^{-1}$ .

#### PERCEPTUAL RESPONSES

Although the investigation of the actual physical capabilities of the workers was essential to obtain objective assessments of any improvements in the physical work capacity of the workers following their participation in the work-hardening programme, there is a general acceptance that as important a factor is the worker's perception of the physical demands required of them. Using the Rating of Perceived Exertion scale, an attempt was made to allow the workers the opportunity to communicate their perception of the effect of the programme on their physical work capacity.

It is clearly evident from *Table XVIII* that the subjects' perceptions of their physical work capacity following their ten-week involvement in the occupation-specific work-hardening

**Table XVIII:** Perceptual responses collected at the pre- and post-conditioning laboratory test sessions.

|     |                        | CONDITION             |              |                        |              |
|-----|------------------------|-----------------------|--------------|------------------------|--------------|
|     |                        | 60°.sec <sup>-1</sup> |              | 120°.sec <sup>-1</sup> |              |
|     |                        | PRE                   | POST         | PRE                    | POST         |
| RPE | $\bar{x}$ :<br>(S.D.): | 13<br>(9.01)          | 13<br>(9.34) | 13<br>(7.89)           | 11<br>(8.60) |

programme did not alter. Although the lack of differences in the responses is attributed to a lack of understanding of the subjects' comprehension of the Borg RPE scale, it is interesting to note the diversity of responses recorded which is similar to the diversity of cardiovascular and strength measures recorded during the pre- and post-conditioning testing sessions.

## DISCUSSION

This study was concerned with the need for more effective strategies in the reduction and rehabilitation of occupational disability, specifically low-back pain, within the South African industrial environment. Because this environment is one in which manual labour predominates, it was hypothesized that involvement in an occupation-specific work-hardening programme, which sought to improve the physical work capacity of the employees involved, would result in an improved ability of the workers to cope with the physical task demands of their jobs and in turn reduce the ergonomic stress index and hopefully the onset of musculoskeletal disorders, specifically low-back pain, and/or the period of disability for the

injured worker.

The presented data suggests that there was indeed a trend towards an improvement in the physical work capacity of the subjects following their ten weeks of work-hardening. According to Curtis *et al.* (1994), such a finding may be attributed to the combined aerobic and strength elements of the work-hardening programme. Curtis and his associates conducted a similar study with similar findings and concluded that without a combination of aerobic and strength components dramatic gains in task performance capability cannot be expected.

The results of the present study indicate that the subject group as a whole demonstrated an above average level of cardiovascular conditioning prior to their participation in the work-hardening programme. This level of cardiovascular conditioning was not unexpected because of the subjects' backgrounds in manual labour, which has been equated with strenuous physical exercise (Larson and Michelman, 1973). Large gains in cardiovascular fitness were therefore not expected for the majority of the subjects. In addition, research findings have shown that improvements in cardiovascular fitness depend on the intensity, duration and frequency of training (Robert *et al.*, 1995). Chapter One's section on the *limitations* of this study explained how these factors were inadvertently dictated by the industries where the project was conducted. Unfortunately the benefits gained by working with actual manual labourers *in situ* meant that the author had to comply with the time restrictions dictated by management in the industries. Furthermore, a physical activity questionnaire conducted at the pre-conditioning laboratory testing revealed that 44% of the subjects participated in a form of regular rigorous aerobic activity outside of the workplace. These subjects displayed an especially high level of cardiovascular conditioning which would also explain the above

average pre-cardiovascular conditioning recorded for the group as a whole.

As a result there was no significant change in the aerobic capacity of the subject group as measured by the group's performance in the Harvard Step Test following the ten-week period of work-hardening. These findings are in agreement with those of Leino *et al.* (1994) who observed no change in the aerobic capacity of lumberjacks following a period of work-hardening. They too attributed this to the lumberjacks' already high level of activity during their working day.

However, the significant reduction in the group's mean **peak working** heart rate measured *in situ* and mean **working** heart rate measured following the higher velocity of isokinetic strength testing ( $120^{\circ}.\text{sec}^{-1}$ ) indicate that the subjects did experience an improvement in their cardiovascular condition. Although the above measure of **working** heart rate was recorded in the laboratory, it was done so following a strength test at a velocity that the subjects are accustomed to working at during the execution of their daily occupational tasks. The significant reductions in **peak working** and **working** heart rate are therefore possibly more important than the non-significant results of the Harvard Step Test due to the fact that these heart rate measures are more occupation-specific.

In addition, the diversity apparent amongst the cardiovascular measures presented in *Tables XII* and *XIII* indicate that a percentage of the subjects were in a relatively poor physical condition prior to their participation in the work-hardening programme. These relatively lower levels of conditioning may be attributed to age, inactivity outside of the workplace as

well as the fact that a few of the subjects were new to manual materials handling tasks. In accordance with the findings of Genaidy (1991), it could be argued that these subjects experienced considerable gains in aerobic capacity as noted by reductions in their **reference**, **working** and **recovery** heart rates as well as an improved performance during the post-conditioning Harvard Step Test.

According to Cox (1981), studies have shown that an increased level of cardiovascular fitness could positively influence workers' fatigue levels and their ability to work through minor illnesses. This fact along with the knowledge of the physical demands of the subjects' occupational tasks makes it gratifying to see the above gains in aerobic capacity experienced by the more poorly physically conditioned subjects as well as the significant reductions in mean **peak working** heart rate measured during the *in situ* task analyses and the mean **working** heart rate measured immediately following isokinetic trunk strength testing at a velocity of  $120^{\circ}.\text{sec}^{-1}$ ; these plus the reduction in the mean **resting blood pressure** measures of the group as a whole are most encouraging responses.

As Fisher and Jensen (1991) highlight, blood pressure is significantly higher during heavy work involving the arms. For this reason it would be dangerous for workers suffering from hypertension to be involved in physically demanding manual materials handling tasks, such as the tasks presented in *Figure 10*, as this would result in additional strain on the functioning of the heart. The fact that blood pressure was significantly reduced following the period of work-hardening may therefore be seen as particularly beneficial.

Although the group as a whole exhibited a good level of cardiovascular fitness at the pre-

conditioning test sessions leaving a relatively small margin for improvement during the work-hardening programme, this same level of conditioning was not obvious in their musculoskeletal performance as substantial pre-post differences were recorded for most of the strength values. There could be two reasons for this. Firstly, according to Fisher and Jensen (1990), although hard physical labour will stimulate an increase in strength, manual labour does not result in maximal strength gains because *maximum overload*<sup>#</sup> cannot be applied. Secondly, the physical activity questionnaire conducted at the pre-conditioning laboratory test session revealed that only 28% of the subjects were involved in a strength training programme as opposed to the 44% involved in some form of aerobic activity.

Indeed, the results of the strength testing illustrate that there was a significant improvement in hand grip strength and in trunk strength when tested at a velocity of  $60^{\circ}.\text{sec}^{-1}$ , following ten weeks of work-hardening. In a similar study, Genaidy *et al.* (1994) recorded an 11% improvement in arm strength, and a 29% increase in back strength following a period of physical conditioning. The results of this study indicate a 19% improvement in arm strength and 24% improvement in back strength following the subjects' ten-weeks of work-hardening.

Although significant differences were recorded during trunk testing at the slower velocity ( $60^{\circ}.\text{sec}^{-1}$ ), the results indicate that this was not the same for trunk testing at  $120^{\circ}.\text{sec}^{-1}$ . Perrin (1993) emphasizes that the trunk constitutes more than 50% of the total mass of the body and that this substantial mass of the trunk makes acceleration to higher velocities

# Maximum overload relates to the fact that muscles become stronger over a period of time when they lift heavier weights than normal. The load must however increase to maintain the overload until maximum overload is achieved.

difficult. Indeed, it was apparent during the testing that the subjects struggled to perform at the required velocity, specifically during trunk extension where recorded values were as low as 60Nm, for **peak torque** and 61J for **work output** even at the post-conditioning session. For this reason Perrin (1993) believes that the assessment of trunk strength should be done at slower velocities as he reports that reliability of trunk testing has been found to decrease with increases in test velocity. Although the results of the present study would seem to be in agreement with the findings of Perrin (1993), in reality workers' natural lifting speeds are often in excess of  $120^{\circ}.\text{sec}^{-1}$  (Li, 1995) and the subjects should therefore not have struggled to perform at the higher velocity. Specificity of training during the work-hardening programme offers a possible explanation for the lack of significant improvements in trunk strength when tested at a velocity of  $120^{\circ}.\text{sec}^{-1}$ .

Although it was not the intention of the work-hardening programme to train the individuals to work at slow velocities, the majority of the subjects had had no prior strength training experience and the exercises were therefore performed slowly in order to prevent injuries from occurring. A future recommendation would therefore be that if the programme was able to continue for a longer period of time, the workers should train at higher velocities once they have mastered the various strength exercises.

The pre-conditioning *in situ* task analyses revealed that the subjects were involved in physically demanding lifting activities throughout their day. According to several authors (Chaffin and Park, 1973; Reimer *et al.*, 1994), the results of previous studies have identified the importance of trunk function in relation to low-back pain. Prospective employees with lifting strength capabilities at or below the requirements of strenuous manual materials

handling tasks are therefore at increased risk for sustaining a low-back injury. Consequently, improving the strength of the workers' trunk musculature would seem essential.

The effects of work-hardening on the subjects' trunk strength was however, mixed. Measures of **total work** showed that following the period of work-hardening dynamic trunk flexor and extensor strength improved significantly when tested at  $60^{\circ}.\text{sec}^{-1}$ , but only dynamic trunk extensor strength showed a significant improvement when tested at a velocity of  $120^{\circ}.\text{sec}^{-1}$ . Although **peak torque** values increased significantly during trunk flexion at  $120^{\circ}.\text{sec}^{-1}$ , Reimer *et al.* (1994) point out that in fact **total work** is a better indicator for the dynamic situation encountered during actual work performance as it represents force in relation to the entire range of motion tested. Conversely, **peak torque** simply measures a single point in time where the greatest force is generated.

One may postulate that the significant improvements in the measures of **total work** are also indicative of an improved resistance to fatigue of the trunk flexor and extensor muscles. A high level of endurance implies that a given level of performance can be continued for a relatively longer time. Indeed, at the beginning of the ten-week period the subjects were unable to complete 20 consecutive sit-ups or trunk hyperextensions, whilst by the end of the ten-weeks they were able to complete 200 of each of these exercises. A high level of endurance reduces the possibility of a repetitive strain injury, especially important in industries like the ones investigated in this study where the tasks are repetitive and demanding in nature, for example loading and unloading in delivery operations.

The trunk strength results in *Table XVI* show that the only one where no differences were

recorded during trunk testing at a velocity of  $60^{\circ}.\text{sec}^{-1}$ , was between the pre- and post-conditioning mean flexor values of **peak torque**. It is possible that this may be as a result of the fact that the exercise used for strengthening the trunk flexors was the *sit-up*. As such body weight supplies the necessary resistance. If additional free weights had been used to increase the resistance and thus achieve a system of progressive overload, it is probable that more substantial gains in the trunk flexor's **peak torque** measures may have been achieved. This could be a further recommendation for future studies in this area.

The presented data on dynamic sagittal muscle balance does not clarify the ambivalence of the current literature. On the one hand, Perrin (1993) reports that numerous studies have shown that the trunk extensors tend to produce more force than the trunk flexors when tested at lower velocities, whereas the present study found the trunk extensors to be consistently weaker than the trunk flexors when tested at  $60^{\circ}.\text{sec}^{-1}$  at the pre-conditioning test session (see *Figures 14, 15 and 16*). There may be two possible explanations for this. Firstly, the subjects may have had weaker trunk extensors in comparison to their trunk flexors and it is therefore particularly interesting to note that at the post-conditioning test session the extensors produced a higher peak torque value than the flexors when tested at a velocity of  $60^{\circ}.\text{sec}^{-1}$ . Secondly, it was observed during the testing that some of the subjects appeared to put less effort into trunk extension, regardless of several instructions and regular encouragement, than they put into trunk flexion.

Thompson *et al.* (1985), on the other hand, found that at higher velocities there was an increase in trunk flexion force so that these values exceed those of trunk extension. The results of the present study revealed that this was indeed true for the flexor and extensor

muscle strength values measured at a test velocity of  $120^{\circ}.\text{sec}^{-1}$ .

Despite the above inconsistencies with the literature, of relevance is that the strength of the trunk extensors improved relative to that of the trunk flexors over the ten-week period of work-hardening. This is important considering the demanding nature of the lifting tasks that the subjects are involved in on a daily basis.

In addition, regardless of whether the improvements in strength were significant or not, according to Fisher and Jensen (1990) and contrary to some reports large, rapid increases in strength should not be expected and a 5% gain in strength per week over a period of several weeks should be considered extraordinary. The results of the study indicate that on average a 2% increase per week occurred in a number of the strength measures over the ten-week period of conditioning. This is a notable improvement if one considers that trained muscles respond more slowly to strength training (consider that some degree of muscular training existed amongst the group as a result of their occupational activities) and people gain strength slower as they get older. According to Fisher and Jensen (1990) men are most responsive up to about age 25, younger than the average age of the group which was 33.64 years (SD 7.55). In addition, the strength improvements were only slightly lower than those recorded by Asfour *et al.* (1984) and Genaidy (1991) in similar studies. This was to be expected as the subjects used in the studies of Asfour and his associates (1984) and Genaidy (1991) were male college students, inexperienced in manual handling tasks. On the other hand, as previously mentioned, the results of the present study were on par with the results of Genaidy *et al.* (1994). Genaidy and his associates also made use of employees within industry, accustomed to manual materials handling tasks.

The significant improvements in strength during grip strength testing and trunk flexion and extension are especially relevant to the reduction of musculoskeletal injuries, for as Fisher and Jensen (1990) recognise, an increase in muscular strength is critical for the optimal performance of manual materials handling tasks within industry. Note should be taken of Genaidy *et al.* (1992) and Waters *et al.* (1993) who recognise it to be the physical demands of many industrial operations which are responsible for the multitude of musculoskeletal disorders reported in industry. Muscular strength therefore plays an important role in protecting individuals from injury. According to Fisher and Jensen (1990), several studies have found lack of strength, or an imbalance in strength, to be a factor in the high incidence of occupational injuries. As mentioned, strong muscles increase body control and joint stability and thus the ability to minimise the incidence of injury.

Unfortunately, despite the improvements in strength, the subjects' ratings of perceived exertion remained unchanged over the ten-week conditioning programme. Strangely, this finding is in agreement with those obtained on college students (Genaidy *et al.*, 1989; Genaidy *et al.*, 1990; Genaidy 1991) and employees in industry (Genaidy *et al.*, 1994) although these studies occurred over a shorter period of time.

Considering attempts in the past to apply objective restrictions to lifting and other manual materials handling tasks in order to prevent occupational musculoskeletal injuries, specifically low-back pain, it is interesting to note the large variation in strength capabilities of the working sample selected in this study alone. As mentioned in the review of literature, restrictions on what and how much to lift clearly have shortcomings in that they are unable to account for the substantial inter-individual strength differences clearly evident in the

working population.

On a final note, in 1973 Larson and Michelman recognized that the potentials of participation in physical conditioning for human development and adjustment to the surrounding environment, in this case the industrial environment, are not only physical in nature, but also have social, emotional and cultural significance. Consequently, in addition to the significant differences between the pre- and post-conditioning cardiovascular and strength measures, a qualitative assessment of the work-hardening programme was provided by management at the dairy. The dairy's managing director, Robin Aliston, felt that the work-hardening programme had not only achieved success in terms of the improvements in the physical condition of their workers but recognised the programmes' worthwhile educational and psychosocial component as well:

"Apart from the obvious gains in productivity and the decreases in down time, there has been a noticeable improvement in team spirit. It has also become an integral part of our own new programmes concentrating on the development of people in the workplace."

## CHAPTER FIVE

### SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

#### AIMS OF THE STUDY

In view of the relative lack of attention given the occupational health of South African workers, this study sought to establish a more effective strategy in the reduction and rehabilitation of occupational disability within South African industry.

As a result of previous research which has demonstrated that employee physical incapacity is a contributing factor in the etiology of lower back pain and other musculoskeletal disorders resulting from manual materials handling (NIOSH, 1981; Asfour *et al.*, 1984; Kesley and Golden, 1988; Ayoub and Mital, 1989; Genaidy *et al.*, 1989; Genaidy *et al.*, 1994), the study attempted an holistic examination of the effects of participation in a prophylactic occupation-specific work-hardening programme on the physical work capacity of a group of South African manual labourers.

The aim of the research was to establish whether workers would experience any improvement in their cardiovascular, strength and perceptual responses following a ten-week involvement in a conditioning programme.

A further objective of the study was to evaluate the nature of the manual materials handling tasks the workers were involved in as a potential source of musculoskeletal stress and to educate the workers in more efficient execution of these tasks in order to further reduce the

possibility of occupational injury, specifically low-back pain. Much of the literature view the nature of the task as one of the major determinants of occupational disability (Chaffin and Park, 1973; Andersson, 1981; Klein *et al.*, 1984; Bush-Joseph *et al.*, 1988; Ayoub and Mital, 1989; Magnusson *et al.*, 1990; Punnett *et al.*, 1991; Burdorf *et al.*, 1993; Waters *et al.*, 1993; Genaidy *et al.*, 1994; Lindström *et al.*, 1994; Marras *et al.*, 1995). It was for this reason that *in situ* task analyses and situational risk assessments were conducted.

A multidisciplinary approach to the examination of the effect of the work-hardening programme on the physical work capacity of the labourers was undertaken specifically because the etiology of low back pain is so multifactorial. The questions addressed aimed at determining whether or not there were any significant differences between the measures of cardiovascular condition, muscular strength and perceptual responses recorded at the pre- and post-conditioning testing sessions both *in situ* and in the laboratory.

## METHOD

The study sample was selected from three local Grahamstown industries and ultimately comprised of twenty-five adult Black and Coloured manual labourers involved in physically demanding occupational tasks on a daily basis.

Two task analyses were conducted *in situ* and involved an assessment of the workers' tasks, a measure of peak and average working heart rates and a measure of the workers' perceptual responses to the demands of their task. The first task analysis was conducted pre-

participation in the work-hardening programme in order to obtain a working understanding of the physical requirements of each subject's daily occupational tasks, which along with data from the pre-conditioning test session and situational risk assessments, helped in the compilation of the work-hardening programme, whilst the second task analysis was conducted post-participation in the programme in order to note any improvements in the workers' execution and perception of their task.

In addition to the *in situ* assessments the subjects were tested on two separate occasions within the Department of Human Movement Studies, i.e. pre- and post-participating in the work-hardening programme. These test sessions consisted of obtaining cardiovascular measures of reference, working and recovery heart rates as well as resting blood pressure and isokinetic strength measures of concentric grip strength and trunk muscles (extensors and flexors). The subjects' perceptual responses were measured immediately following the trunk strength tests using Borg's RPE scale. During the pre-conditioning test session a medical history; personal details of age, occupation (in present and previous employment), period of employment (present and previous); and morphological measures of stature and mass were also obtained. During the post-conditioning session all aspects tested in the pre-conditioning laboratory tests were re-tested and changes noted.

The ten-week involvement in the occupation-specific work-hardening programme involved a half hour commitment twice a week, in which the subjects participated in aerobic, strength and flexibility exercises, as well as specific occupational activities in order to educate the workers in efficient and safe body mechanics. The aim of the work-hardening programme was to improve the physical work capacity of the subjects involved in the programme as well

as incorporate a certain educational element in order to address the multifactorial problem of lower back injuries.

The work-hardening programme was administered by the author allowing contact to be maintained with the workers over the ten-week period. In addition, once the ten-week period was over the workers were provided with their results from the pre- and post-conditioning tests and encouraged to continue their involvement in physical activity.

Statistical analyses of the results was performed as follows: basic descriptive statistics were conducted to acquire an awareness of the physical work capacity of the group and a series of related T-tests were conducted in order to determine whether any significant differences existed between the pre- and post-conditioning results. The 0.05 level of significance was chosen for these statistics.

## **RESULTS**

This study analyzed the holistic effect of a ten-week occupation-specific work-hardening programme on the physical work capacity of a group of manual labourers involved in physically demanding tasks on a daily basis. On the whole the results revealed that involvement in the ten-week of work-hardening appeared to have a positive effect on the physical work capacity of the subjects as measured by cardiovascular, and strength responses. This finding is in agreement with the findings of a number of other studies investigating the area of physical conditioning on the physical work capacity of individuals (Asfour *et al.*

1984; Genaidy, 1991; Curtis *et al.*, 1994; Genaidy *et al.*, 1994; Robert *et al.*, 1995).

The pre-programme results indicated that the subjects demonstrated an above average level of cardiovascular conditioning prior to their participation in the work-hardening programme. This above average level of aerobic fitness was attributed to the high level of physical activity within the workplace, as well as the involvement of a percentage of the workers in rigorous and regular physical activity outside of the workplace. However, there was clear evidence of a substantial amount of diversity amongst the physical condition of the subjects. The expansive range in ages and the years of involvement in physically demanding tasks could be argued to be possible reasons for these substantial individual differences.

The results of the Harvard Step Test illustrated that no significant improvements were measured in the aerobic capacity of the group as a whole. This finding was in accordance with those of Leino *et al.* (1994) who recorded an improvement in the muscle function of lumberjacks involved in worker-oriented physical fitness courses, but no change in their aerobic capacity.

Likewise no significant differences were recorded in the measures of **reference, working** (*in situ* and Cybex:60°.sec<sup>-1</sup>) and **recovery** heart rates. Although training adaptations manifest in several ways, as pointed out by Fisher and Jensen (1990), a decrease in resting and submaximal heart rates, as well as a reduction in recovery time is more apparent in previously unconditioned individuals.

Significant differences were however, measured between the pre- and post-measures of mean **peak working** heart rate measured *in situ* as well as mean **working** heart rate measured

immediately following isokinetic strength testing on the **CYBEX 6000** at a velocity of  $120^{\circ}.\text{sec}^{-1}$ , indicating that the effect of the workload on the cardiovascular system of the subjects at higher velocities was significantly reduced at the post-conditioning test session. Significant differences were also recorded between the pre-post measures of **resting blood pressure**, a possible indication of improved cardiovascular efficiency of the workers after their ten-week involvement in the work-hardening programme.

Intra-individual results demonstrated that the more poorly conditioned subjects experienced considerable improvements in their aerobic capacity following the period of involvement in the work-hardening programme. This finding was in agreement with that of Genaidy (1991).

Genaidy *et al.* (1992) and Waters *et al.* (1993) believe that occupational musculoskeletal injuries are primarily of over-exertion in nature where the worker exceeds personal physical capability limits. Strength improvements following a period of work-hardening would therefore be advantageous in the reduction of musculoskeletal injuries in labour-intensive work environments. Within the present study significant increases in grip and trunk strength were recorded following the ten-week period of work-hardening. The significant increases in trunk flexor and extensor strength were however, more prevalent when tested at a velocity of  $60^{\circ}.\text{sec}^{-1}$ . The subjects thus experienced an overall improvement in their strength performance, which was more notable at the slower velocities. The lack of significant trunk strength results at a velocity of  $120^{\circ}.\text{sec}^{-1}$  was attributed primarily to specificity of training as during the ten-week work-hardening programme the subjects performed their strength training exercises at slower speeds than their natural lifting speeds in order to prevent any training injuries from occurring. It appears that the subjects thus struggled to accelerate their

trunk movement at the higher velocity of testing. When considering these responses it is worth noting that Perrin (1993) reported that reliability of testing decreases with increases in velocity.

One would hope that the significant improvements recorded during trunk strength testing are indicative of the workers' abilities to be better able to cope with the physical demands of their tasks. Unfortunately, no differences were measured between the subjects' ratings of perceived exertion recorded, both *in situ* and during trunk strength testing, at the pre- and post-conditioning sessions. However, it is interesting to note that these findings are in agreement with those obtained on college students (Genaidy *et al.*, 1989; Genaidy *et al.*, 1990; Genaidy 1991) as well as employees in industry (Genaidy *et al.*, 1994) although these studies were conducted over a shorter period of time.

Comparisons of personal reporting were made upon completion of the ten-week work-hardening programme; where initially 68% of the subjects had experienced lower back discomfort and 56% of the subjects had experienced upper back and neck discomfort at the pre-conditioning *in situ* task analyses, these numbers were reduced to 44% and 40% respectively indicating that the subjects perceived an improvement in their physical work capacity and a reduction in physical strain. This reduction in back complaints may be attributed to the increase in strength of the trunk extensors relative to the trunk flexors following the ten-week period of work-hardening plus an awareness of handling the objects more appropriately, thus minimizing the stress being placed on the body.

General observations and managerial comments indicated that the subjects were found to have

a positive attitude and commitment towards participation in the work-hardening programme and although over the ten-week period the study experienced a drop out of fifteen of the original forty subjects, a number of new workers volunteered to join, and adhered to the programme.

## **HYPOTHESES**

In light of these results the three sub-hypothesis relating to cardiovascular, strength and perceptual responses will be discussed separately.

### **CARDIOVASCULAR ASSESSMENT:**

#### **Heart Rate Responses**

Although there were two significant improvements in the heart rate responses, overall the cardiovascular assessment revealed no change in the pre- and post-conditioning testing.

The findings led one to tentatively accept the null hypothesis that there were no differences between the pre- and post-conditioning measures of heart rate following the subjects participation in the ten-week work-hardening programme.

## **Blood Pressure**

With significant differences evident in the resting blood pressure measures, the findings of this study led one to reject the null hypothesis that there was no difference between the pre- and post-conditioning measures of resting blood pressure following the subjects participation in the ten-week work-hardening programme.

### **STRENGTH ASSESSMENT:**

#### **Grip Strength**

The significant improvements in the grip strength of the subjects led one to reject the null hypothesis that there was no difference between the pre- and post-conditioning measures of grip strength following the subjects participation in the ten-week work-hardening programme.

#### **Trunk Strength**

Significant differences were recorded between the pre- and post-trunk flexion measures of total work and average power and trunk extension measures of peak torque, total work and average power recorded during testing at a velocity of  $60^{\circ}.\text{sec}^{-1}$ , as well as between the pre- and post-measures of peak torque recorded during trunk flexion at a velocity of  $120^{\circ}.\text{sec}^{-1}$ , and total work recorded during trunk extension at this same velocity.

These findings of the study led one to reject the hypothesis that there was no difference

between the pre- and post-conditioning measures of trunk strength following the subjects participation in the ten-week work-hardening programme.

#### PERCEPTUAL RESPONSES:

##### Ratings of Perceived Exertion

The findings of this study led one to tentatively accept the null hypothesis that there were no differences between the pre- and post-ratings of perceived exertion measured both during *in situ* testing and following strength testing on the **CYBEX 6000** subsequent to the subjects' participation in the ten-week work-hardening programme.

In light of the above hypotheses it would appear that the work-hardening programme did not result in a significant improvement in all the measured responses. However, the results of the present study do indicate a general improvement in the subjects' physical work capacity, as measured by the cardiovascular and strength results, following the period of work-hardening.

#### CONCLUSIONS

The manual materials handling which occurs in South African industry would appear to be of a particularly demanding nature. Workers new to such physically demanding tasks are therefore at a considerable risk of experiencing musculoskeletal injuries which are of over-

exertion in nature. Although the worker involved in this type of work does become physically hardened over the years, he remains vulnerable to occupational injuries as a result of fatigue, overuse and increasing age.

As a result of the varying amount of years workers have been involved in manual materials handling as well as the number of ethnic groups indigenous to South Africa, industries have to deal with an extremely diverse occupational population. Indeed, a substantial diversity in physique and physical condition was evident amongst the manual labourers within the three industries investigated in this study. These individual differences resulted in large variations in the response of the workers to the ten-week work-hardening programme.

Because no significant improvements were measured in the aerobic capacity of the subject group as a whole, one may conclude that a work-hardening programme will have little effect on the cardiovascular condition of workers who have already been exposed to physically demanding manual labour for a period of years. The programme may nonetheless be successful in improving the cardiovascular fitness of workers new to manual materials handling.

The method of testing improvements in aerobic capacity is however important as the subjects demonstrated significant improvements in heart rate responses considered occupation-specific. The work-hardening programme may therefore have resulted in important training responses regarded as more specific to the nature of the tasks the workers are involved in on a daily basis.

The effect of the programme on the muscular strength of the workers indicated that a ten-week period of work-hardening can significantly improve the strength performance of employees engaged in manual labour within industry, regardless of the length of time these workers have been involved in manual materials handling. However, in light of the significant improvements recorded during grip strength as well as trunk strength testing at the slower velocity ( $60^{\circ}.\text{sec}^{-1}$ ), one may conclude that the training which occurs during the work-hardening programme will result in very specific strength outcomes.

The perceptual responses recorded during this study would seem to indicate that the Rating of Perceived Exertion (RPE) scale is not a reproducible measure of exertion within a wide variety of individuals. In the present study it is argued that the language barrier resulted in a misconception amongst the workers of the meaning of the RPE scale and as a result no differences were recorded during the pre- and post-conditioning RPE ratings.

Finally, the workers were enthusiastic about their participation in the programme and there was a keen interest and support from management. The work-hardening programme therefore appeared to be successful in not only improving the physical capacity of the workers, but also in the fostering of improved attitudes toward work and the building of a team spirit amongst the workers as well as between the workers and management.

## **RECOMMENDATIONS**

Although it appears that it is possible to increase the physical work capacity of individuals

engaged in manual handling tasks through the use of an occupation-specific work-hardening programme, whether such an approach can be used to significantly reduce the frequency and severity of musculoskeletal injuries resulting from manual materials handling must still be ascertained. Future studies in this area should therefore conduct a longitudinal study in order to determine whether there is any correlation between improved physical work capacity and decreased injury statistics in industry.

During the present study, due to the constraints of working within a busy daily schedule, the work-hardening programme was only run twice a week for a period of thirty minutes. It is hypothesized that this may be one of the reasons for the lack of significant changes in the aerobic capacity of the subjects. Future studies should therefore attempt to conduct the programme at least three to four times a week for a period of forty-five minutes in order to allow more time for the aerobic, strength, flexibility and specifically the occupation-specific training.

Furthermore, considering the lack of significant changes in the aerobic capacity of the group, it would be worthwhile investigating the effects of an occupation-specific work-hardening programme on only the physical work capacity of workers new to manual materials handling tasks and following this with a longitudinal study in order to obtain injury statistics for this group of workers.

As a result of the very specific strength outcomes of the work-hardening programme, future work-hardening programmes should also concentrate on faster velocities of strength training in order to accommodate for the naturally high speed of lifting which occurs in industry.

Due to the fact that no differences were found to exist between the pre- and post-conditioning ratings of perceived exertion, and that this finding is in agreement with other similar studies in the literature, it would appear that the use of the RPE scale must be carefully considered in future studies. Within the setting of this project, more time could possibly be spent purely demonstrating the meaning of the RPE scale through the use of drawings (Scott, 1986) and dramatisation in order to explain to the subject group the meaning and use of the exertion scale.

Lastly, it is essential that the improved physical work capacity of the subjects be maintained if management wishes to ensure that there is a resulting decrease in occupational musculo-skeletal injuries. Future research must consider methods in which to maintain such a programme within South African industry in order to preserve the improved work capacity of the employees. However, industrialists must, in addition, recognise the crucial need within local industries to not only equip the worker to cope with the demands of his task but to design/redesign the task to fit the worker.

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**APPENDIX A:**

INITIAL LETTER TO INDUSTRIES

INFORMED CONSENT INFORMATION SHEET

SUBJECT CONSENT FORM

March 1996

Dear Sir

Occupational injuries, specifically low-back pain, are problematic within most industries. Reducing the extent of occupational injuries is therefore of major concern to local industry, particularly as manual labour is still so prevalent within South Africa. The significant role that ergonomics can play in enhancing the work environment has gained international recognition and today there is clear evidence of the substantial benefits of ergonomic intervention within industry. This is reflected in the reduced occurrence of musculoskeletal injuries, improved worker well-being and increased productivity.

I am at present working on a Masters degree in the Department of Human Movement Studies at Rhodes University and my supervisor is Professor Scott. The title of my thesis is:

"The effect of work-hardening on the physical work capacity of manual labourers in South African industry"

The main objective of this study is an investigation into *work-hardening* as a proactive approach to low-back injuries. In the past, most work-hardening programmes have been used in a rehabilitative setting in order to correct the deconditioning in the worker with musculoskeletal injuries and to achieve maximal functional improvement to facilitate the individual's return to work. What I am proposing is to place a greater emphasis on primary health care and preventative medicine in order to reduce the incidence and socioeconomic cost of occupational injuries, specifically low-back pain. As such, work-hardening programmes can be used as an effective strategy in not only the rehabilitation, but also the possible reduction of musculoskeletal injuries and low-back pain which result from physically demanding tasks. The basic principle is to introduce individuals, who due to the physical demands of their job are prone to injury, to a programme which emphasizes functional improvement and therefore increased physical working capacity.

In order to investigate the possible benefits of a work-hardening programme I would like to work with manual labourers actually in industry. I therefore require the assistance of those

in industry. It is for this reason that I am approaching you in the hope that your interest in the reduction of musculoskeletal injuries within your industry will motivate you to participate in the study.

This letter is simply an initial reach out; should you be interested in the project I would like to arrange to come and see you sometime to explain the outline of the project in more detail. Your co-operation would be greatly appreciated and I do firmly believe that there will be a beneficial spin off, not only for the individual workers but for the overall output of your industry.

Yours Sincerely

Karyn Jacka

**RHODES UNIVERSITY**  
**DEPARTMENT OF HUMAN MOVEMENT STUDIES**  
**INFORMED CONSENT INFORMATION SHEET**

**Project Title:**

The effect of work-hardening on the physical work capacity of manual labourers in South African industry.

**General Aim of Project:**

The main objective of this study is an investigation into work-hardening as a method to improve the physical work capacity of manual labourers within South African industry, in an attempt to proactively reduce the incidence and socioeconomic cost of occupational injuries, specifically low back pain.

**Subject Pool:**

Subjects are manual labourers, between the ages of 20 and 50 years, engaged in physically demanding tasks within local industry.

**Basic Procedure:**

The study will consist of two pre- and two post-physical work capacity examinations, inbetween which you will be required to participate in a work-hardening programme for a period of 8-10 weeks. Of the two pre- and two post-examinations one will occur *in situ* (i.e. at your workplace) and the other in the laboratory (i.e. at the Human Movement Studies Department).

During the *in situ* task analyses your working heart rate will be recorded whilst I take note of the type of tasks you perform during your daily routine. The second examination in the department will take place during your work day, in accordance with management, and will involve a measure of stature, body mass, resting (reference), working and recovery heart rate, back and arm strength. This second session will be approximately one hour in duration.

The recordings of heart rate will require you to wear a heart watch for a period during your working day as well as during the submaximal aerobic test performed within the department.

Strength testing will be conducted on the **CYBEX 6000**. This is a highly sophisticated piece of equipment which allows one to measure the force, work and power output of specific muscles, in this case those specifically related to your task at work.

The work-hardening programme will take place twice a week within a practical area of your work place. The programme is a conditioning one which will consist of two phases - the general conditioning phase and the specific job simulation phase. Both phases aim to improve your physical working capacity. The programme will run for between 20 - 30 minutes.

#### **Risks and Benefits:**

There are no risks involved during these physical examinations nor during involvement in the work-hardening programme. The programme will be designed to suit your specific needs following the outcome of the physical examinations performed in the laboratory. Your performance will be strictly monitored in order to prevent any possible negative results. It is hoped that the benefits you will accrue will include an improved ability to cope with the physical demands of your job as well as a feeling of improved health. In addition, as a result of the educational component of the work-hardening programme, it is hoped that you will perform your task more effectively thus further reducing the risk of injury.

**SUBJECT CONSENT FORM**

I, \_\_\_\_\_, have been fully informed of the research entitled; "**The effect of work-hardening on the physical work capacity of manual labourers within South African industry**" and do hereby give my consent to act as a subject in the above named research. I am fully aware of the procedures involved as well as the potential risks and benefits attendant to my participation as explained to me verbally and in writing. In agreeing to participate in this research, I waiver any legal recourse against the researchers or Rhodes University, from any and all claims resulting from personal injuries sustained. This waiver shall be binding upon my heirs and personal representatives. I realise that it is necessary for me to promptly report to the researchers any signs or symptoms indicating any abnormality or distress. I am aware that I may withdraw my consent and may withdraw from participation in the research at any time. I am aware that my anonymity will be protected at all times, and I agree that the information collected may be used and published for statistical or scientific purposes.

I have read the information sheet accompanying this form and understand it. Any questions which may have occurred to me have been answered to my satisfaction.

|                       |                   |                 |
|-----------------------|-------------------|-----------------|
| _____<br>(PRINT NAME) | _____<br>(SIGNED) | _____<br>(DATE) |
|-----------------------|-------------------|-----------------|

Subject (or legal representative):

|                       |                   |                 |
|-----------------------|-------------------|-----------------|
| _____<br>(PRINT NAME) | _____<br>(SIGNED) | _____<br>(DATE) |
|-----------------------|-------------------|-----------------|

Person administering informed consent:

|                       |                   |                 |
|-----------------------|-------------------|-----------------|
| _____<br>(PRINT NAME) | _____<br>(SIGNED) | _____<br>(DATE) |
|-----------------------|-------------------|-----------------|

Witness:

## APPENDIX B:

### PRE- AND POST-CONDITIONING *IN SITU* DATA COLLECTION

RPE Scale

Assessment of Task Characteristics

*In Situ* Ratings of Perceived Exertion and Body Part  
Discomfort

*In Situ* Pulse Rate Curve

## RPE SCALE

- 6.
7. **KANCINCI KAKHULU**
- 8.
9. **KANCINCI**
- 10.
11. **KANCINANE NOKO**
- 12.
13. **NZINYANA**
- 14.
15. **NZIMA**
- 16.
17. **NZIMA KAKHULU**
- 18.
19. **NZIMA KAKHULU KANYE**
- 20.

## TASK CHARACTERISTICS

RECORDER: ..... DATE:

FIRM/ CODE: ..... SITE: .....

TASK IDENTITY: ..... TASK CODE: .....

NUMBER OF WORKERS:  JOB/TASK ROTATION  YES  NO

DURATION                      FREQUENCY

TASK               

          (h)    (% shift)    (per h)    (per shift)

LIFT RATE:  lifts/min

WORK RATE:                        SHIFT DURATION: (h)

                    self-paced    imposed

**LOAD/CONTAINER SPECIFICATIONS**

STABILITY:  firm     liquid     loose     other    .....

specify

DIMENSIONS:    L     B     H     *If more than one dimension exceeds 70cm conduct a RISK assessment\**

MASS (kg):                       HAND HOLD: .....

specify

Symmetrical

Asymmetrical

(delete one)

SHAPE:

(diagram if necessary)

**LIFT SPECIFICS (cm)**

*If less than 30cm or greater than 170cm, conduct a RISK assessment\**

START/FINISH                      VERTICAL                      START/FINISH

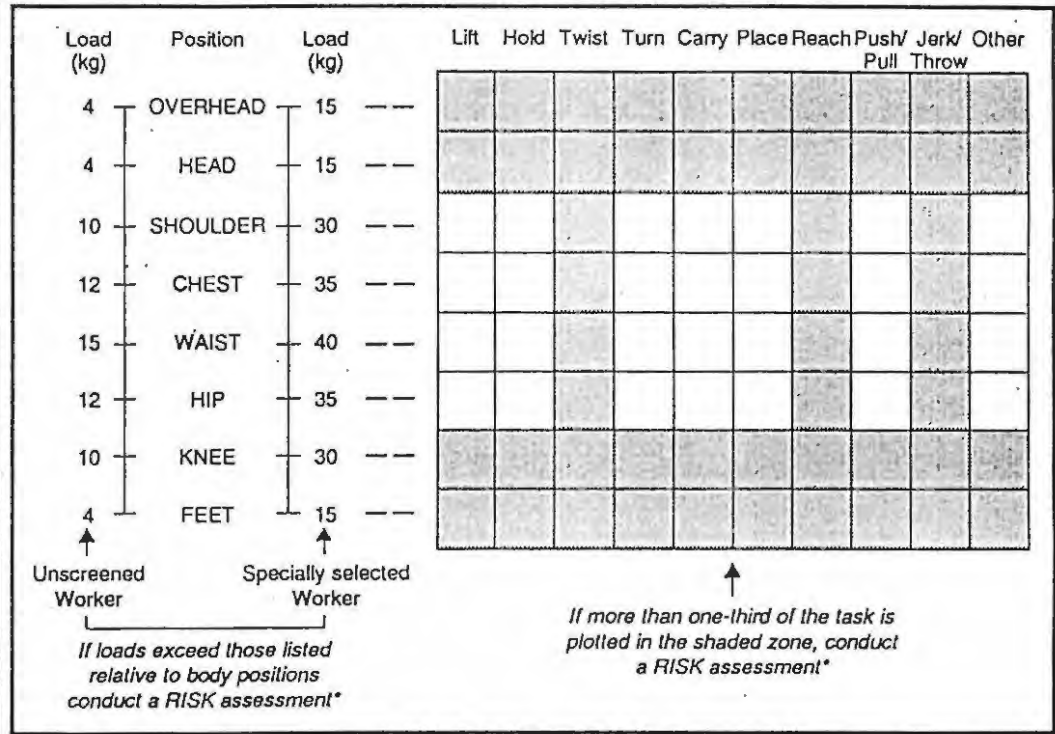
                    initial height                      final placement

*If greater than 40cm conduct a RISK assessment\**

START/FINISH                      HORIZONTAL                      START/FINISH

                    initial distance                      final placement



**COMMENTS**

.....

.....

.....

.....

.....

•  CONDUCT RISK ASSESSMENT     YES     NO

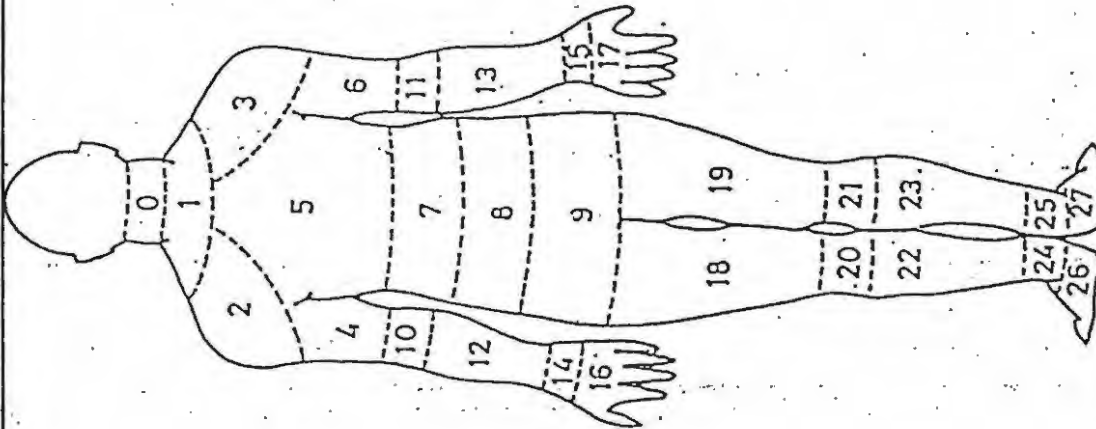
*NOTE: When In doubt, answer YES.*

NAME:

AGE:

RATINGS OF PERCEIVED EXERTION:

|     |     |    |
|-----|-----|----|
| min | RPE | HR |
| min | RPE | HR |
| min | RPE | HR |
| min | RPE | HR |
| min | RPE | HR |



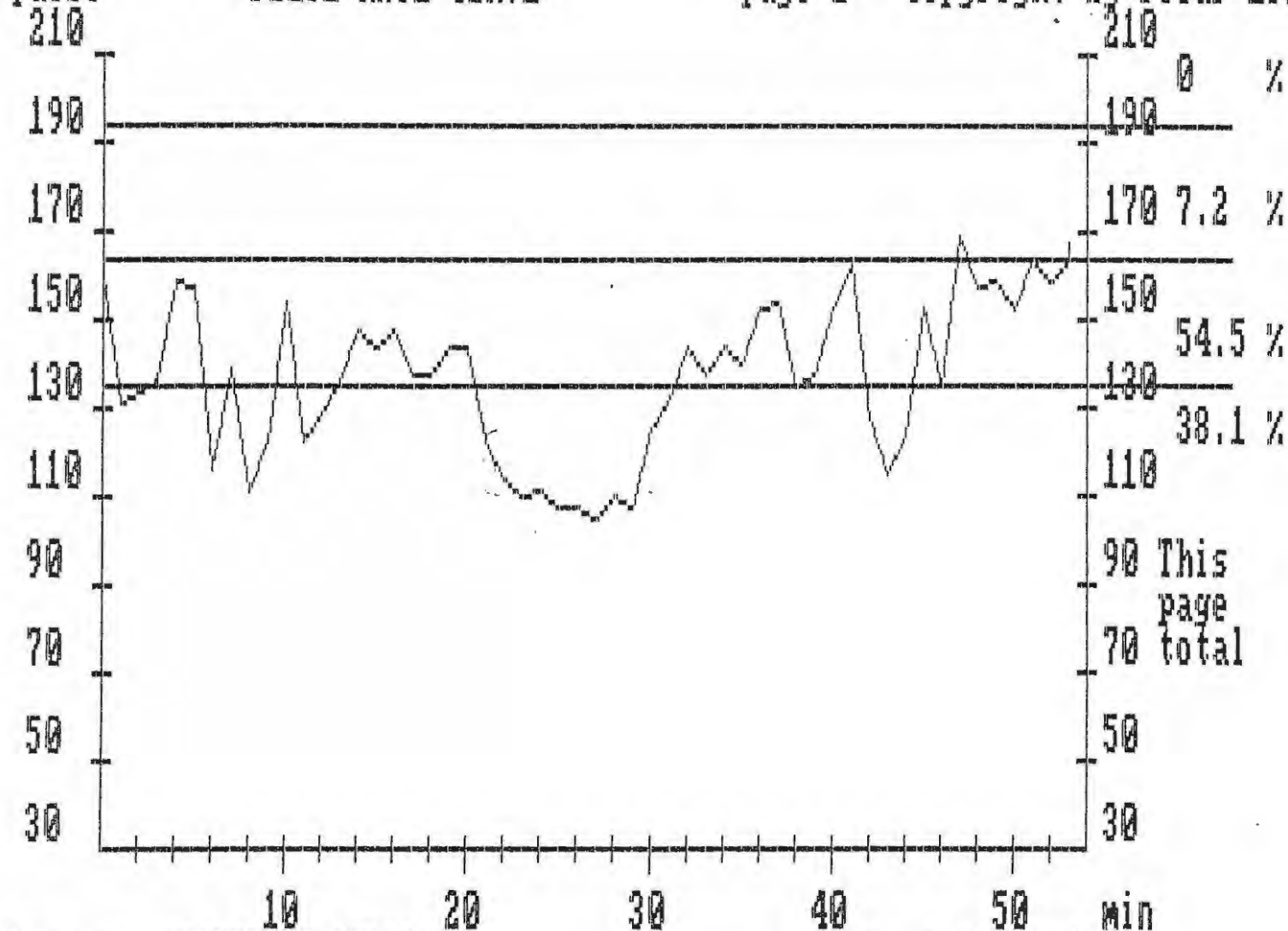
THE BODY MAP FOR EVALUATING  
BODY PART DISCOMFORT, EITHER BY RATING OR RANKING

pulse

# PULSE RATE CURVE

page 1

Copyright by Polar Electro



167

Source: RECEIVER MEMORY  
 Heart Beat Sum: 7404  
 Press Shift + PrtSc

Date : 05-17-1996  
 Average HR: 134 (Whole file)

90 This  
 page  
 70 total

**APPENDIX C:**

PRE- AND POST- CONDITIONING LABORATORY DATA COLLECTION

Pre-Test Data Sheet

Pre-Test Medical History and Physical Activity Questionnaire

Post-Test Data Sheet

**PRE-TEST DATA SHEET**

Subject code: \_\_\_\_\_

Collection date: \_\_\_\_\_

**Personal Details:**

Age: \_\_\_\_\_

Occupation: \_\_\_\_\_

How long have you worked at \_\_\_\_\_ ? \_\_\_\_\_

Where did you work prior to \_\_\_\_\_ and for how long? \_\_\_\_\_

**Morphological Details:**

Stature (m): \_\_\_\_\_

Mass (kg): \_\_\_\_\_

BMI (kg.m<sup>-2</sup>) \_\_\_\_\_

**Cardiovascular Details:**

Age-predicted maximum heart rate (b.min<sup>-1</sup>): \_\_\_\_\_

Reference heart rate (b.min<sup>-1</sup>): \_\_\_\_\_

Blood pressure (mmHg): systolic \_\_\_\_\_ diastolic \_\_\_\_\_

**Harvard Step Test:**

Duration (s): \_\_\_\_\_

(< 300s): 30s pulse count \_\_\_\_\_ score \_\_\_\_\_

(= 300s): recovery 60-90s \_\_\_\_\_

120-150s \_\_\_\_\_

180-210s \_\_\_\_\_ score \_\_\_\_\_

**Cybex 6000 Isokinetic strength testing:**

Back strength: (60) RPE \_\_\_\_\_

(120) RPE \_\_\_\_\_

HR \_\_\_\_\_

HR \_\_\_\_\_

**MEDICAL HISTORY**

Age: \_\_\_\_\_

|              |             |  |
|--------------|-------------|--|
| Hypertensive | Hypotensive |  |
|--------------|-------------|--|

Have you ever suffered a heart attack?

|     |    |
|-----|----|
| YES | NO |
|-----|----|

Has anyone in your immediate family suffered a heart attack?

|     |    |
|-----|----|
| YES | NO |
|-----|----|

Are you suffering from a cold/flu at present?

|     |    |
|-----|----|
| YES | NO |
|-----|----|

Do you ever experience low back pain when lifting?

|     |    |
|-----|----|
| YES | NO |
|-----|----|

If yes, do you ever experience back pain with pain radiating to your legs?

|     |    |
|-----|----|
| YES | NO |
|-----|----|

Do you ever experience muscular pain in the upper part of your back and neck?

|     |    |
|-----|----|
| YES | NO |
|-----|----|

Do you ever experience any other kinds of pain?

|     |    |
|-----|----|
| YES | NO |
|-----|----|

**PHYSICAL ACTIVITY QUESTIONNAIRE**

Occupation: \_\_\_\_\_

How many hours a week do you work? \_\_\_\_\_

Do you walk, cycle or catch a bus/taxi to work? \_\_\_\_\_

Do you play a sport (eg. run/play soccer)? \_\_\_\_\_

If yes, how many times a week? \_\_\_\_\_

Do you do any type of strength training?

|     |    |
|-----|----|
| YES | NO |
|-----|----|

If yes, how often? \_\_\_\_\_

**POST-TEST DATA SHEET**

Subject code: \_\_\_\_\_

Collection date: \_\_\_\_\_

**Morphological Details:**

Mass (kg): \_\_\_\_\_

BMI (kg.m<sup>-2</sup>) \_\_\_\_\_

**Cardiovascular Details:**

Reference heart rate (b.min<sup>-1</sup>): \_\_\_\_\_

Blood pressure (mmHg): systolic \_\_\_\_\_

diastolic \_\_\_\_\_

**Harvard Step Test:**

Duration (s): \_\_\_\_\_

(< 300s): 30s pulse count \_\_\_\_\_

score \_\_\_\_\_

(= 300s): recovery 60-90 \_\_\_\_\_

120-150s \_\_\_\_\_

180-210s \_\_\_\_\_

score \_\_\_\_\_

**Cybex 6000 Isokinetic strength testing:**

Back strength: (60) RPE \_\_\_\_\_

(120) RPE \_\_\_\_\_

HR \_\_\_\_\_

HR \_\_\_\_\_

**APPENDIX D:**

SITUATIONAL RISK ASSESSMENT

- LIFTRISK 2.0 -

MALE operator - AVERAGE  
Stature (cm) [168.00]

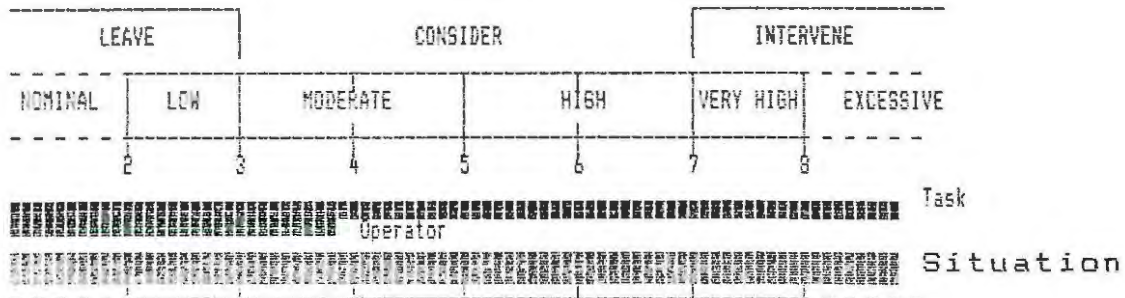
Mass (kg) [30.00] Age (yr) [30 - 39]  
 Frequency (lifts/min) [9.00] Arm Strength (N) [500.00]  
 Reach (cm) [109.00] \* Back Strength (N) [1500.00]  
 Stretch (cm) [207.00] \* VO2 max (ml/kg/min) [47.00]

NOTE : \* indicates value off scale.

Task inputs over upper parameter limits.  
 Predisposing Operator Risk 3.81

WEIGHTED SITUATIONAL RISK (2 to 8 scale)  
 Mass + Arm Strength 4.86  
 Mass + Back Strength 4.86  
 Frequency + Age 4.33  
 Frequency + VO2 max 5.00  
 Reach + Arm Strength 6.00

The situational risk for THIS worker at THIS task involves a complex interaction of the above inputs and/or assumed (default) characteristics. On the basis of this analysis the overall situational risk is identified as follows :



**EXCESSIVE SITUATIONAL RISK**

**Intervention Strategy :**

|          |                          |                      |
|----------|--------------------------|----------------------|
| Task     | Reduce Stretch           | [Rated "Off Scale" ] |
|          | Reduce Reach             | [Rated "Off Scale" ] |
|          | Reduce Frequency         | [Rated "High" ]      |
|          | Reduce Mass              | [Rated "Heavy" ]     |
| Operator | Improve Aerobic capacity | [Rated "Average" ]   |
|          | Improve Back Strength    | [Rated "Average" ]   |
|          | Improve Arm Strength     | [Rated "Average" ]   |

Code : [3.81 0.63 7.10 3.81 0.30 1.00 1.00 0.25 0.60] 0.00

