RISK FACTORS AND THE EFFECTIVENESS OF BACK BELTS IN THE PREVENTION OF BACK PAIN AMONGST FORKLIFT DRIVERS SUBJECT TO WHOLE BODY VIBRATION EXPOSURE.

By

DARREN MARK JOUBERT
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DECLARATION

I, Darren Mark Joubert, hereby declare that the work on which this thesis is based is my original work (except where acknowledgements indicate otherwise), and that neither the whole work nor any part of it has been, is being, or is to be submitted for another degree in this or any other university.

The research described in this thesis was carried out in the Department of Community Health, under the supervision of Dr L. London.

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DEDICATION

I dedicate this work to my family, especially Michelle and Sarah for their never-ending support, for lending an ear and putting up with me through the rocky peaks and seemingly never-ending valleys of the research journey.

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ABSTRACT

Motivation: Back pain is a major cause of absenteeism, lost work time and increased compensation and medical costs amongst workers and has been estimated to cost $ 20 billion annually in the United States. Back pain has long been associated with the driving of forklifts, and is a complex area of occupational health and safety, having many risk factors leading to musculo-skeletal injury. The health effects in this occupational group in South Africa, could be affecting upwards of 90 000 forklift drivers, and has a great direct and indirect influence on peoples health at work as well as productivity and the economy.

Purpose: To characterise the problem of back pain amongst forklift drivers with a view to reducing the morbidity from back pain, by evaluating the effectiveness of the use of back belts.

Aim: To identify risk factors associated with back pain amongst forklift drivers at Portnet (handling wharf side cargo) in two cohorts of forklift drivers one using back belts and one control group, and to evaluate the relationship between back pain, the occupational environment (ie: forklift driving) and other associated factors, in order to establish the effectiveness of back belts in decreasing the severity and prevalence of back pain amongst forklift drivers.

Objectives:

1.) To describe demographic and other relevant back pain risk factors in the two cohorts and to identify any significant differences between them.

2.) To characterise the compliance and frequency of use of the back belts by the user group.

3.) To measure vibration experienced in typical driving activities in the study population in order to characterise whole-body vibration exposures of the study subjects.

4.) To ascertain opinions and beliefs regarding back belts amongst users.

5.) To analyse, characterise and determine if any significant differences exist between the two groups as to the prevalence and severity of back pain, and what factors are associated with increased risk of back pain. Specifically to identify whether **(a.)** The frequency and /or intensity of use of back belts are associated with reduced risk for back pain, when controlling for all other risk factors, and **(b.)** Whether other factors modify this relationship.

Study Design: Cross Sectional Study Design

Subjects: Drivers of 3, 4, 4.5 and 5 ton forklifts in the permanent employment of Portnet, Durban, from the Point, Maydon Wharf (back belt group) and Combi Terminal (control group)areas.

Main Outcome Measures: Onset of back pain after starting driving, prevalence of regular back pain (ever), point prevalence (pain today), 1 year prevalence, severity of back pain, duration of pain, and treatment/medication sought for back pain.

Results: The majority of forklift drivers (89%) in the study suffer from chronic back pain that is of a constant severity, and is significantly linked to the driving activities. The back belt wearers were more likely to suffer from back pain than the non-users (92% VS 80%). However, the belt wearers reported less severe pain than the control group, which could indicate the presence of a placebo effect related to the belt use. The belt users were more likely to suffer from pain of a longer duration, with less fluctuation in severity than the controls, and therefore a more constant type of pain (44% vs 41%). The majority of belt wearers expressed the belief that the belts helped to reduce the back pain (81%). However, more objective measures do not bear out this conclusion when prevalence and severity of pain are compared to the control group. Drivers with back pain were more likely to wear the back belts and compliance was reduced as the prevalence of pain was reduced. These results may have been confounded by variations in the whole-body vibration exposure in the various test areas, and the inability to characterise individual whole-body vibration exposures and dose-response relationships.

Conclusion: The prevalence of back pain in this study was high, with most drivers suffering form pain in the lower back region (79%), which was characterised as constant or chronic pain experienced either during or shortly after driving. Whole-body vibration levels were high in all test areas (1.9 m/s^{-2}, 1.3 m/s^{-2} and 1.1 m/s^{-2} predicted), and consistently exceeded the EEC machinery directive standards of 0.5 ms^{-2}. Compliance with the use of back belts amongst drivers was high (90%), with most drivers (76%) wearing the belts on a regular basis whilst driving. The evidence for the effectiveness of back belts as a control measure against whole-body vibration remains obscure, and other more tested controls such as engineering, administrative and training of drivers should be implemented to address the problem following a holistic approach

Key Words: Whole-body vibration, back belts, kidney belts, forklift, drivers, back pain, lower back pain, risk factors.

ABBREVIATIONS

ACGIH:	American Conference of Governmental Industrial Hygienists
AIHA:	American Industrial Hygiene Association
ANSI:	American National Standards Institution
CSIR:	Centre for Scientific and Industrial Research
EMG:	Electromyogram
ISO:	International Organisation for Standardisation
NIOSH:	National Institute for Occupational Safety and Health
NSC:	National Safety Council
OEL:	Occupational exposure limit
PPE:	Personal Protective Equipment
RMS:	Root-mean-square
SABS:	South African Bureau of Standards
TLV:	Threshold Limit Value
WMSD:	Work-Related Musculoskeletal Disorders

Definitions (see appendix A)

CHAPTER 1:
WHOLE-BODY VIBRATION AND BACK PAIN.

1.1 INTRODUCTION

Musculo-skeletal disorders include a group of conditions that involve the nerves, tendons, muscles and supporting structures (such as intervertebral discs). They represent a wide range of disorders, which can differ in severity from mild periodic conditions to those which are severe, chronic and debilitating. Some musculo-skeletal disorders have specific diagnostic criteria and clear pathological mechanisms (like hand/arm vibration). Others are defined primarily by the location of pain and have more variable or less clearly defined pathophysiology (like back disorders).

1.1.1 The Importance of Musculo-Skeletal Disorders and Vibration Hazards: Global and South African Experience

Musculo-skeletal disorders are a significant health problem both internationally and for South Africa. Linda Rosenstock, the director of the National Institute for Occupational Safety and Health (NIOSH), in the USA, reported [1] that musculo-skeletal disorders are among the most prevalent medical problems in the USA, affecting 7% of the population. They accounted for 14% of physician visits and 19% of hospital stays. Sixty-two percent of persons with these disorders reported some degree of limitations on activity compared to 14% of the population at large. The precise cost of musculo-skeletal disorders is not known, although a conservative estimate by NIOSH is $13 billion annually. A National Safety Council report [2] indicated that back injuries were the most frequent disabling work injury in the USA., and in 1995 there were approximately 900,000 disabling back injuries. Back injuries were also the most highly compensated injury type, accounting for almost one third of all compensation. Others have estimated the cost at $ 20 billion annually. However regardless of the exact cost, the problem is large in health and economic terms.

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1. **Report submitted to the Sub-Committee on Workforce Protection on the 21st May 1997.** Available on-line at URL:http://www.cdc.gov.niosh/nioshfin.html.
2. **National Safety Council report cited in American Industrial Hygiene Association position paper on ergonomics 1999**, available online at URL:http://www.aiha.org/papers/ergo/html.)

The most comprehensive review of international occupational epidemiological literature on musculo-skeletal disorders was undertaken by NIOSH, covering more than 2000 scientific studies and concluded that the literature supported a positive relationship between the development of low back disorders and the three main categories of workplace risk factors: 1) lifting and forceful movements, 2) bending and twisting in awkward postures and, 3) whole-body vibration exposure (Rosenstock 1997).

In response to this report and the scientific literary evidence NIOSH, recognised that ergonomic intervention programmes could make a difference and more research was needed. The National Occupational Research Agenda (NORA, 1999 Available on-line at URL:http://www. cdc.gov/niosh/norhmpg.html.) was then developed in partnership with over 500 stakeholders in the public and private sectors. The agenda provided a framework to guide occupational safety and health research, not just at NIOSH, but for the whole of the USA Together with this NIOSH announced a partnership with three other federal institutes, and the largest single infusion of funding ever for occupational safety and health research, a sum of $ 8 million, to support grants for studies in areas of high priority. Two of these 21 areas included research into work-related musculo-skeletal disorders, and research to evaluate existing or new interventions to protect workers from job-related musculo-skeletal disorders. This is the present situation in the USA With the extent and magnitude of the problem having been identified, and resources for research and control interventions being supported and funded, solutions are now being sought.

The Federal Republic of Germany has, in recognition of past research data and evidence of the effects of occupational whole-body vibration exposure on professional drivers, made Whole-Body Vibration - induced spinal disorders a compensatable occupational disease, No: 2110 in 1993.(Duipus 1994). This includes "diseases of the lumbar spine from disc degeneration caused by long term (mainly vertical) whole-body vibration exposure whilst sitting, which have lead to the discontinuation of all work which was or could be responsible for the origin, the deterioration or the recurrence of the disease."

More recently in 1997, the Health and Safety Executive (HSE) in the United Kingdom, has published a free leaflet titled "In the Driving Seat" warning of damage to drivers backs from vibrational shocks and jolting, and suggests a number of practical and inexpensive measures that employers can do to reduce employees exposure to whole-body vibration (HSE 1997.Available on-line at URL:http://www.open.gov.uk/hse/press/e978.htm). The HSE has also recently published an Agricultural Information sheet No: 20 entitled "Health hazards from whole-body vibration caused by mobile agricultural machinery" and has commissioned research to estimate the numbers of people exposed to whole-body vibration categorised by industry and occupation.

In contrast, musculo-skeletal disorders and especially whole-body vibration exposure in the South African workplace has in the past been a neglected area of occupational health and safety, and is presently not receiving any priority attention from the Department of Labour or industry. As a result, whole-body vibration is one of the least identified, least understood and least controlled of all the occupational hazards in South Africa today. It is most commonly encountered in vehicle drivers, where the transmission of vibration is usually from the vehicle being driven, through the seat and floor, and up into the body tissues, muscles and skeletal system of the operator. These vehicles may be anything from the smallest forklift truck, up to the largest trucks used in the mining and quarrying operations.

Past economic sanctions and poor exchange rates have resulted in widespread usage of outdated equipment, and vehicles in South African industry today after many years of service. With the average new forklift today costing more than a luxury German passenger sedan due to the ever weakening rand value and rising exchange rates, one can anticipate that older vehicle types and models will continue to be used in South Africa for some time to come.

In addition, South African workplaces have many other competing hazards that are often more visible, resulting in the concentration of control measures on more common and noticeable industrial hazards such as chemical hazards, noise, heat stress and even illumination which may be relatively easier and cheaper to measure and evaluate. Monitoring and evaluation of whole-body vibration is very costly and requires specialised expertise and relatively sophisticated equipment which may cost over R 750 000. [3]

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[3] 1 $ equivalent to 7.5 South African Rand (1999 exchange rates).

Much of South Africa's whole-body vibration research originates in military settings, including studies done on pilots, ship motion studies and tank and other armoured vehicles, particularly by ARMSCOR, the governmental organisation that developed military equipment and vehicles for the South African National Defence Force. The knowledge gained has been very specialised, but limited in distribution. Only recently has this expertise become more widely available with transformation and semi-privatisation of quasi-governmental organisations in South Africa, with the service being extended to general industrial settings.

Research into whole-body vibration in South Africa has therefore been limited by these factors, resulting in a general lack of local knowledge, expertise and data in the field of vibration exposure. This lack of knowledge regarding whole-body vibration issues extends to the general public and those employed in driving occupations, resulting in a hazard unrecognised becoming a hazard uncontrolled.

A unique factor that has arisen in South Africa amongst some whole-body vibration exposed groups such as forklift drivers, is the belief amongst employees and employers that a back belt can be used to protect the lower back from the harmful effects of whole-body vibration and associated pain. Anecdotal evidence suggests the use of these devices is increasing in South Africa, with the active promotion by vendors of the use of belts in the absence of concrete research evidence as to the effectiveness of these devices in protecting the back. It is not clear where this belief arose. Perhaps it is linked to the use of kidney belts by endurance and motor-cross riders to support the kidneys from vibrational shocks while riding motor-cycles over uneven, rough and bumpy terrain. However, as will be discussed later, this type of vibration exposure is not applicable to occupational whole-body vibration exposure circumstances.

There is a lack of specific ergonomic legislation in South Africa that can offer the same protection for occupational/professional drivers as provided for other occupational groups covered by the various regulations framed under the Occupational Health and Safety legislation in South Africa. The position of the Chief Director: Occupational Health and Safety, Department of Labour in South Africa, is that more research and scientific evidence was needed in South Africa before any new ergonomics regulations would be brought out or even considered (personal communication: F. Salie, Cape Town, 10 Sep 1998) Thus it appears that timely research in the fields of ergonomics and particularly vibration could greatly benefit workers exposed to hazardous whole-body vibration conditions, by helping to prompt appropriate legislation.

This chapter encompasses a review of some of the most pertinent, relevant and up to date literature available, regarding the complex and interrelated problems posed by whole-body vibration on an occupationally exposed group such as forklift drivers. The problem upon investigation has many aspects that need to be considered, as each factor including the driver, his/her driving environment, vehicle and vibration as a physical hazard have a bearing on the overall exposure characteristics and health effects.

1.1.2 Information Gathering: Sources and Resources

Many sources of information were consulted in the literature search including, human, printed as well as electronic sources, as discussed below.

a) Human Resources

Many individuals were consulted on various aspects including experts in the fields of Ergonomics, Epidemiology, Whole-body vibration, Research Methodology, Statistics, Engineering, and Medicine, where up to date information and guidance was obtained on relevant factors. These consultations either took place face to face during meetings at conferences or via e-mail, which enabled international consultation with some of the major leading names in these fields especially ergonomic and whole-body vibration. (See pg 145 for list)

b) Hard Copy Resources

The printed resources included books, journals, local and international government legislation and standards, local and international guidelines and codes of practice, marketing material, handbooks and other technical publications such as agency reports. These proved very useful in obtaining a greater insight into the history of the problem and the developments over time in the field as well as obtaining relevant and up to date information and data. It also enabled the author to get a greater understanding of the different theories and views of the international community and the perspectives from the medical, engineering and other professional fields.

One very under-estimated resource is the local subject librarian that helped source so many of the journal articles and inter-library loan information sources and was an invaluable ally in gathering and locating information. The journal articles located were invaluable in sourcing other relevant and related articles using the references cited by the author of the original article.

c) Electronic Media

Electronic media have been a great boon in this review in that country boundaries and distances were virtually eliminated which allowed a greater opportunity to access information from around the world and even some local sources. The Internet provided many sources for information with online journal abstracts and databases offering a starting point, and search engines providing many resources and links to sites and people of relevance to the problem. Other sources of information included electronic databases both online and CD-Rom. (See appendix B for list)

The overall objective was to draw together the threads of multi-disciplinary research that may have been carried out in relation to back pain and other health effects, whole-body vibration, back belts and the occupational environment of professional driving, especially in relation to forklifts. Key words used in searches included forklift trucks, whole-body vibration, lower-back pain, sciatic pain, spinal disorders, professional driving, physical stresses, back/kidney belts, ergonomics, occupational stress factors and hazards, postural load, seat design, musculo-skeletal disorders, epidemiology etc. The searches were refined by using the many variations of terminology used in the literature and in different countries eg: back belts, lifting belts, kidney belts, back support belts, abdominal belts, and weight lifting belts. Combinations of these terms were used in searches in order to try and obtain as many relevant documents and references as possible and to exclude the irrelevant information.

1.1.3 Review Outline

The first part of this literature review covers an overall introduction to the current field of whole-body vibration as experienced in the South African and global occupational environments, and then goes further into some of the important general fundamental concepts concerning the physics of vibration, after which more specific concepts are discussed in their relation to humans exposed to vibration in the occupational environment.

In the sections that follow the health effects of whole-body vibration are discussed, with the discussion and inclusion of relevant and up to date epidemiological, whole-body vibration and lower back pain research studies and data.

Instruments of measurement for epidemiological studies are covered next, with specific reference to standardised questionnaires. This section is followed by discussion of international vibration exposure standards and guidelines, and standards for vibration measurement.

Existing whole-body vibration control technologies are then reviewed with discussion on risk factors associated with the occupation of professional driving, personal driver risk factors, and the occupational driving environment as a whole.

The next section covers more information and discussion specific to the use of back or kidney belts with sections on the global perspective, the views of the health and safety community at large, as well as other relevant agencies and organisations. It closes by reviewing other back belt studies conducted around the world and their findings.

The final section of the literature review looks at some fundamental control principles of occupational health and safety and their application to whole-body vibration as an occupational hazard. This is brought to a conclusion with the introduction and discussion of relevant new technological developments for the control of vibration and the exposure of professional drivers that are currently being developed and tested around the world.

1.2 THE PHYSICS OF VIBRATION

1.2.1 Introduction

Vibrations are mechanical oscillations, produced by either regular or irregular periodic movements of a body about its resting position. It is an environmental condition common to all types of vehicles used for human transportation and is also a common condition around heavy industrial and certain hand held tools. The different types of vibration exposures and the possible effects on human health is thus an area of concern in the occupational environment. Some basic vibration concepts and terminology will be covered in this section that will then lead into other pertinent areas.

1.2.2 Some Common Vibration Concepts and Terminology

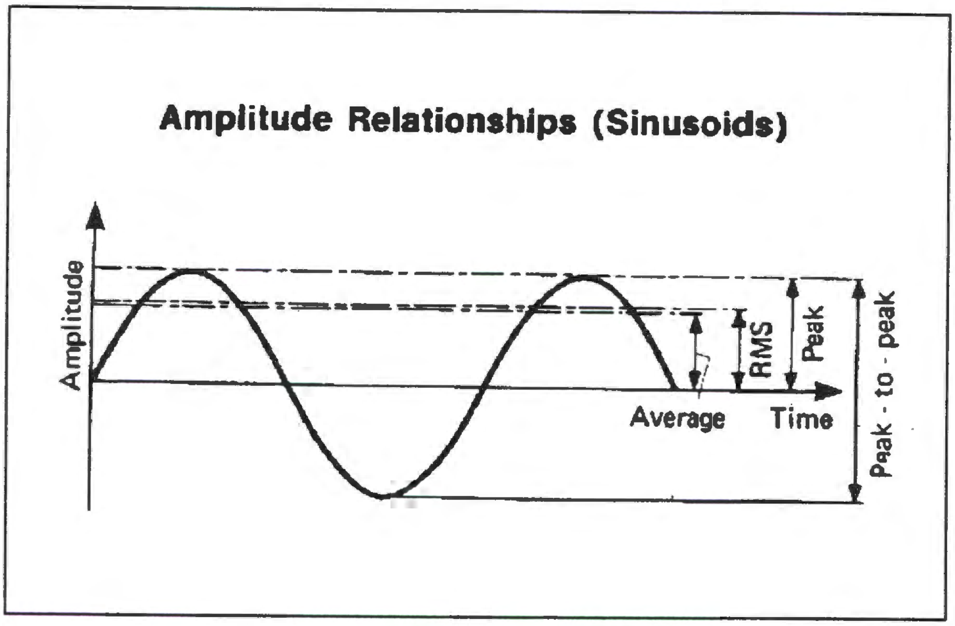
Vibration put simply is any movement which a body makes about a fixed point, this movement can be regular, like the motion of a weight on the end of a spring, or it can be random in nature. The vibration experienced from vehicles is usually a very complex but regular motion with some irregular shock characteristics.

In simple terms the movement of a vibrating body can easily be defined in terms of a few important parameters: the vibration frequency, intensity, and acceleration.

The frequency is essentially an indication of the speed of movement, and is measured in cycles per second or Hertz. Thus the vibrating body is said to have moved through one cycle when it has moved from its fixed point to its highest deviation from the point, back to the lowest deviation, and then returned to the position of the original fixed point. The number of times it does this in a specified time, usually one second is its frequency of movement, or its number of cycles per second (Hz). Vibration spectra can be comprised of many frequencies, all of which can be vibrating at unique levels at the same time (Thalheimer 1996).

Vibration intensity or magnitude is usually specified as the change of position of a body, usually measured from its resting position. Displacement levels can be measured in inches or millimetres. The primary quantity used to describe the intensity of a vibration environment, irrespective of the type of transducer used in the actual measurements is acceleration, which is normally expressed in metres per second squared (m/s^2). The acceleration of a body is the time rate of change of the velocity or speed, and for occupational vibration, the acceleration is the most important quantity since it is proportional to the forces applied to the body of the exposed worker, and it is believed that the forces are the source of damage and harm (DiNardi 1997:469).

Figure 1.1: Amplitude and Root Mean Squared (RMS) values for vibration.



Source: Bruel & Kjaer (1985)

This can be further expressed as root mean squared (RMS), and is useful in vibration measurement as workplace vibration exposures are complex and contain many vibration frequencies. The average can be obtained by summing the squares of the acceleration values measured over time, dividing by the measuring time, and then taking the square root of the resulting value as shown in the equation below. (DiNardi 1997:469)

$$A_{rms} = \sqrt{\frac{1}{T}\int_0^T A^2(t)dt}$$

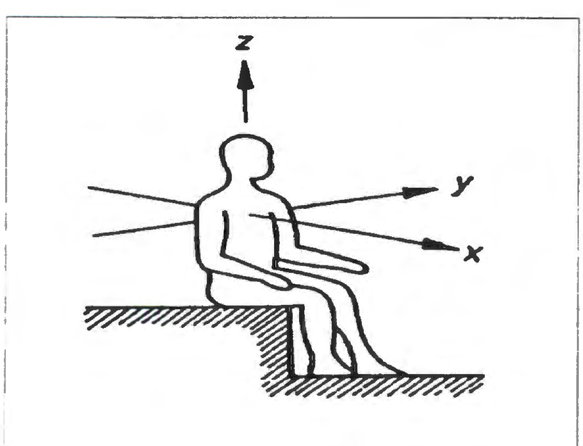
The RMS value of the acceleration is directly related to the energy content of the vibration being measured and has been shown to better simulate a human beings perception of vibration when computed over a one second averaging time. Vibration is also sometimes quantified using a peak value, which represents the highest or (lowest) value, but these are usually more useful for pure sinusoidal vibration curves of constant amplitude (DiNardi 1997:469).

1.2.3 Human Vibration

When we consider the exposures of a human to vibration in the occupational environment we usually consider two main exposure patterns or areas, Hand-arm vibration that primarily originates from the use of hand tools, and whole-body vibration, which is the vibration of the human body as a result of standing on a vibrating floor or sitting on a vibrating seat, often encountered near heavy machinery and or construction equipment, trucks, and other vehicles. For the purposes of this review emphasis will be given to whole-body vibration exposures and characteristics. The main interest is in vibrations transmitted to the body as a whole through the supporting surfaces, namely the buttocks and back of a seated person (ISO-2631 1985).

Human vibration exposure is a complex system of energy, acceleration, and movement of the exposed driver in many directions, but for the ease of quantification and measurement only three co-ordinates or directions are accounted for, namely: Vertical (Z) movement; buttocks to head, Lateral (Y) movement; right side to left side, and Fore-Aft (X) movement; back to chest. These co-ordinates are shown in figure 1.2 below:

Figure 1.2: Co-ordinates of vibration: X, Y, and Z axes of movement of a seated human.



Source: ISO-2631 (1985).

The human body's response to mechanical vibration is not a simple single response that can be identified and noted. There is a diversity of pathways for transmitting the mechanical energy through the body and the effects and receptors are thus widespread and difficult to identify. The vibration can be amplified (increased) or attenuated (reduced) as a result of body posture, the type of seating, tissue matter, body part or system it passes through.

In relation to this factor a phenomenon known as resonance can have a marked effect on the bodies response to vibration energy. Every object has a resonant frequency, i.e. a natural frequency that causes it to resonate, as determined by its relative combinations of mass, stiffness and damping attributes. (Thalheimer 1996) When an object is vibrating at its resonant frequency, it will vibrate at a maximum amplitude which is larger than the amplitude of the original vibration. In essence the original vibration energy has now been amplified or increased and can cause increased response in the human body tissues it travels through. In the human body individual body parts and organs each have their own resonance frequencies and do not vibrate as a single mass.

Table 1.1: Resonance frequency ranges of various body sections.

Body Section / Organ	**Resonance Frequency Ranges**
Eyeball (Intra-ocular Structures)	20 - 90 Hz
Head (Axial Mode)	20 - 30 Hz
Shoulder Girdle	4 - 5 Hz
Chest Wall	10 - 50 Hz
Arm	5 - 10 Hz
Hand	30 - 50 Hz
Abdominal Mass	4 - 8 Hz
Spinal Column	**10 - 12 Hz**
Legs (Knees flexed or Rigid posture)	2 - 20 Hz

Adapted from Bruel and Kjaer (1985).

Studies by Coerman (1968) have shown that in general, the most effective exciting frequency for vertical vibration lies between 4 and 8 Hz, with vibrations of between 2.5 and 5 Hz generating strong resonance in the vertebrae of the neck and lumbar region (amplification of up to 240%), between 4 and 6 Hz resonance in the neck (amplification of up to 200%) and frequencies between 20 and 30 Hz sets up the strongest resonance between the head and shoulders (amplification up to 350%). This amplification phenomenon related to resonant frequencies has a direct bearing on the health effects of whole-body vibration on the drivers of vehicles such as forklifts.

Three main parameters discussed, acceleration, frequency and intensity are all closely related, and this makes it almost impossible to isolate the specific parameter that is affecting physiological reactions, performance or subjective reactions. Unlike many other occupational hazards that have a threshold of exposure where adverse effects are likely to appear in most healthy workers, and where a dose-response relationship is clear, whole-body vibration does not easily lend itself to such simple dose-effect relationships.

1.2.4 Vibration Dose-Response Curves?

In general, the dose-response relationship may be characterised in a graph depicting the relationship between dose received by the exposed worker and his/her physiological response. The dose-effect relationship will depend upon the type of contaminant or hazard , as well as the factors acting upon the hazard and/or individual, but three relationships (see figure 3.1) are generally found:

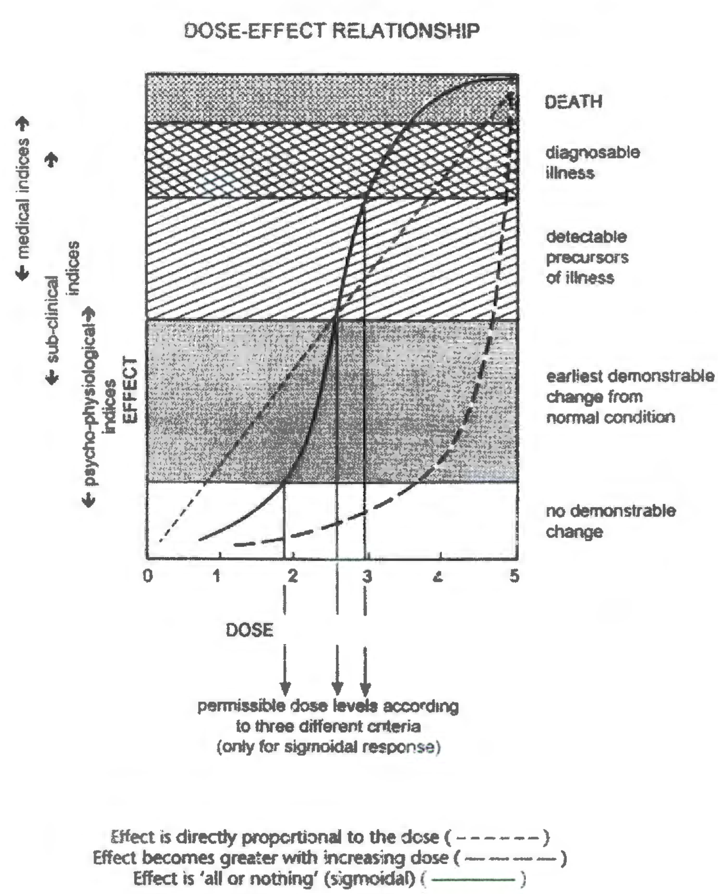
1.) The first may be a simple linear relationship where the response or effect on the human body is directly proportional to the exposure dose received, with an increase in dose having a corresponding increase in effect with death being the ultimate effect. This linear relationship often applies to exposures to industrial chemicals, although more complex dose-response relationships may also apply in certain cases.

2.) The second type is indicated by a hyperbolic curve, or by a non-linear continually increasing function, where at a certain level the increased effect of an increase in dose becomes prohibitive and the affected systems or organs fail, which may ultimately result in death. This is also known as the Ceiling Level or value which should never be exceeded, not even momentarily.

3.) The third type is a sigmoidal or S-shaped curve, and can also be indicated as an "all or nothing" effect where the systems or organs can withstand the dose up to a certain level, where after failure and adverse effects follow rapidly (Schoeman and Schroder 1994).

Other variations on these three dose-response curves are also found. However, dose-response relationships cannot easily be applied to whole-body vibration exposure. Relationships between vibration exposure, frequencies, amplitudes, and accelerations create complex non-linear dose-effect relationships with whole-body vibration exposures, with considerable degrees of uncertainty. A dose-response relationship probably does apply to vibration exposures. However these have not been established as yet with any degree of certainty.

Figure 1.3 Dose-effect (response) relationships.



Source: Schoeman and Schroder (1994).

According to DiNardi (1997), long-term exposure to whole-body vibration has been shown through the many studies conducted on a variety of exposed occupational groups to be harmful to the spinal system. However, most of these studies used cross-sectional study designs for reasons of lower costs, and ease of implementation. Due to the limited numbers and quality of epidemiological studies, firm dose-response relationships are undetermined.

Many factors have contributed to the absence of a clear dose-response relationship, one factor being that there is no specific human receptor for whole-body vibration or a specific target organ, where adverse effects or cumulative damage occurs. Vibration has many complex criteria and parameters that influence the effects that are not fully understood at this time. The associated health effects may be found far from the site of entry due to the influence of resonance of tissues, may only occur after chronic long term exposure, and may have no visible early precursors of disease or disability.

The most up to date British Standards Guide to the Measurement and evaluation of human exposure to whole-body vibration, mechanical vibration and repeated shock, BS 6841-1987, has a specific note regarding dose-response relationships, where it states that current epidemiological studies suggest that back complaints are associated with exposure to prolonged periods of vibration and repeated shock, but there are currently inadequate data to define precise dose-effect relationships. (BS 6841-1987) Similarly, it is not yet possible to provide a definitive dose-effect relationship between whole-body vibration and any other injury.

The latest International Standardisation Organisation (ISO) guideline for the evaluation of whole-body vibration is entitled the Mechanical vibration and shock- Evaluation of human exposure to whole-body vibration (ISO 2631-1997). In the guideline it states that "increased awareness of the complexity of human physiological and pathological response as well as the behavioural response to vibration and the lack of clear, universally recognised dose-response relationship has made it desirable to give more quantitative guidance on the effects of vibration on health and comfort", and the ISO has therefore updated the guidance document (ISO 2631-1997). However even this latest draft does not have specific dose-response information and clear distinctions where safe and harmful exposure levels are. All the research evidence to date has confirmed that exposures to whole-body vibration are associated with certain harmful effects to exposed individuals, but exactly what the physiological and mechanical mechanisms whereby this harm occurs and at what exact levels or limits remains in the arena of future research.

1.2.5 Conclusion

Vibration production and transmission is a complex area that requires a thorough understanding of the physical characteristics and concepts of vibration specific to human exposures. The effects of the fundamental physics of vibration on the human body is also very important to understand in order to ascertain how vibration exposure occurs and what the physiological responses may possibly be.

Much work has been done internationally in the occupational field, principally in transportation, and agricultural settings on off-road vehicles, but this type of work has been limited in South Africa. Although vibration has been measured in so many studies, a useful dose-response relation has not been determined and ongoing research in this area is required.

1.3 PHYSIOLOGY AND HEALTH EFFECTS OF WHOLE-BODY VIBRATION EXPOSURE

1.3.1 Introduction

Lower-back pain is amongst the most common health problems in the world. Lifetime prevalence has been estimated at almost 70% for industrialised countries (Hulshof 1998). Although back pain is not related very often to mortality, it has an enormous impact on morbidity, use of health care facilities and other hidden economic costs, such as compensation, medical costs and loss or reduction in productivity. This is in addition to the effects it can have on the lifestyle and quality of life of an individual, when disability and pain result from these types of injuries.

With an increase in mechanisation and long working hours, exposure to the mechanical energy produced whilst driving vehicles and whole-body vibration can exceed in many cases the ability of the natural protective mechanisms of the body to offer adequate protection against this hazard which can result in harmful effects on the exposed population, usually professional drivers.

Whole-body vibration can cause both physiological and psychological effects ranging from fatigue and irritation, to motion sickness (kinetosis) and to musculo-skeletal tissue damage. The most frequently reported adverse effect of whole body vibration in the literature is lower-back pain, early degeneration of the lumbar spinal system, and herniated lumbar discs. (DiNardi 1997: 469). This arises from ligamentous and muscular strain or structural degenerative changes of the vertebral column induced by mechanical forces, and the pain originates either from irritation of the nerve endings supplying the various structures of the spine such as the outer annulus, ligaments or related muscles, or from irritation and compression of the nerve roots passing through the motion segments. (Bongers and Boshuizen 1990)

More detail on general vibration effects at different frequencies are given in the United States Naval Flight Surgeons Manual (Available on-line at URL:http://www.vnh.org/fsmanual/02/04vibration.html), where it is mentioned that acceleration increases the body's rigidity, reducing its shock-absorbing properties, increasing the transmission of vibration energy to the internal organs. The effects of vibration on the body are partly determined by the frequency ranges involved.

Some relevant points are offered in the Naval Flight Surgeons Manual regarding the effects of frequency on health effects:

- Effects at less than 2 Hz, in the ranges 0.1 to 0.7 Hz most often produce motion sickness in humans, and between 1 and 2 Hz, associated effects are increases in pulmonary ventilation, heart rate, and sweat production above the level considered normal for any other stress present.

- Tolerance from 2 to 12 Hz ranges, is usually limited by substernal or subcostal chest pain, with thresholds at approximately 1 to 2 Gz (up-down motion), and 2 to 3 Gx (fore-aft motion). The etiology of the pain is the same for both axes of vibration: displacement of the abdominal and thoracic viscera induces stretching of the chest wall with torsion at the costochondral junctions of the ribs. Dyspnea is the second most common symptom in this range, apparently with the same etiology as chest pain.

- Cardio-vascular effects are maximised in the Gz axes at 3 to 6 Hz, and in Gx at 6 to 10 Hz. The changes seen are increases in heart rate, arterial blood pressure, central venous pressure, and cardiac output, these are accompanied by a corresponding decrease in peripheral resistance. These changes all resemble nonspecific exercise responses.

- Abdominal discomfort and testicular pain are common complaints due to stretching of viscera and force applied to the spermatic cord, respectively. The effects of vibrations frequencies above 12 Hz are more concerned with effects on performance (vision, speech and fatigue) than physical injuries.

It must be remembered that these general thresholds shown above are for vibration frequencies alone, and the effects indicated will also be influenced by the intensity of the vibrational energy and exposure duration, which all relate to the exposure dose and the phenomenon of resonance.

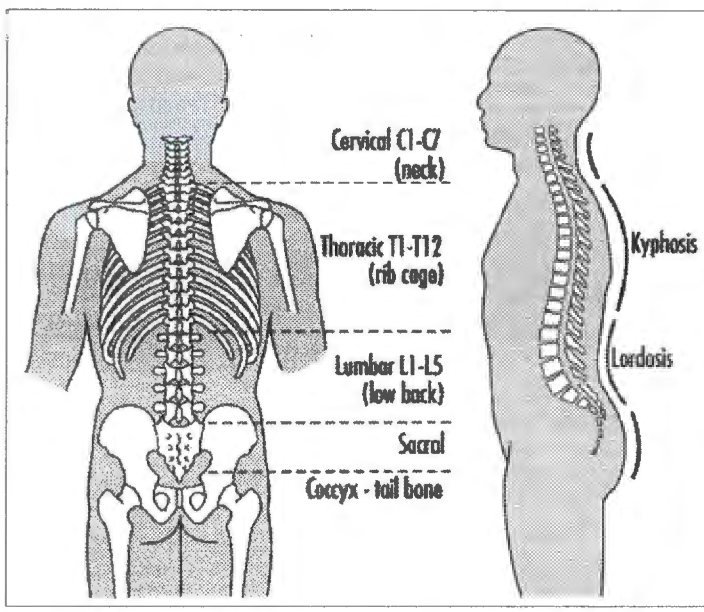
Pope (1993), showed, through dynamic analysis, that vibration and impact conditions as experienced during vehicle driving, can excite the natural frequency of the spine (resonance) and lead to increased spinal loadings. In vivo measurements by Pope *et al* (1987) in which percutaneous pins, with accelerometers attached were implanted in the lumbar region, showed that the resonance frequency of the spine is 4.5 Hz. In a study by Coerman (1968), it was shown that vibrations between 2.5 and 5Hz generates strong resonance in the vertebrae of the neck and lumbar regions with an amplification of up to 240%.

1.3.2 Anatomy and Physiology of the Spinal Column

The vertebral column is made up of five regions consisting of the cervical (neck) region composed of 7 vertebrae, the thoracic (chest), composed of twelve vertebra, the five lumbar (back)vertebrae, the five fused sacral (pelvic) vertebrae, and finally the coccygeal vertebrae, which are also fused. Adjacent vertebrae articulate with one another in two ways, by means of the synovial apophysial joints, and by means of the cartilaginous intervertebral discs. The apophyseal joints are formed by the superior and inferior articular processes of adjacent vertebrae, which articulate with one another via inferior convex and superior concave surfaces, thus the processes of adjoining vertebrae form synovial joints. But while these synovial joints guide and limit motion of the vertebrae, they do not bear the gravitational and other major stresses transmitted through the spine. That function is reserved for the intervertebral discs, the cushion, which separates two vertebrae and collectively they give flexibility to the spine. A disc is composed principally of a tissue similar to fibrous cartilage, surrounded by a tough connective tissue capsule. The cartilage is differentiated into two concentrically arranged parts, a tough outer layer known as the annulus fibrosis, and a soft, viscous almost semi-liquid core, the nucleus pulposus. Since the intervertebral discs must absorb the full force of gravity, and all manner of shocks and vibrations, they sometimes break down by rupture of the connective tissue capsule. In a severe case the herniated (ruptured) disc impinges on the root of a spinal nerve, causing extreme pain.(Solomon and Davis 1983:167)

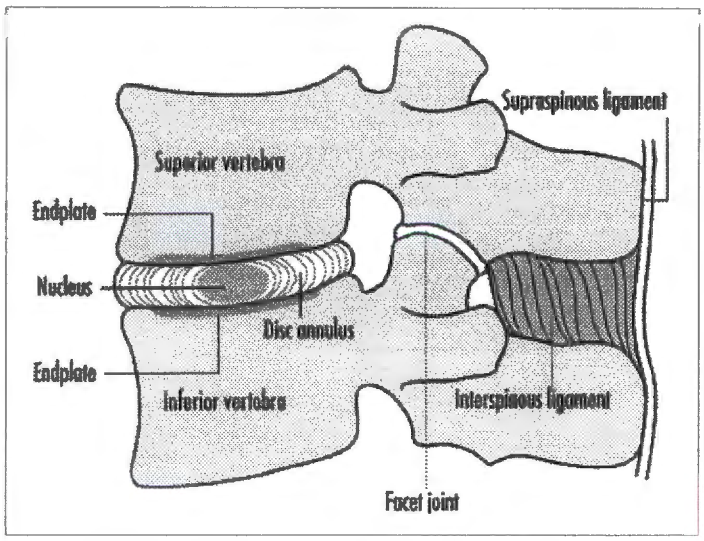
This is a system that is designed to support the body, and all internal and external organs, and protect them from mechanical injury from the outside. Vibrational energy being transmitted from the seat of a vehicle is transmitted to the body of the person, and travels as an energy wave through the tissues, from one type of tissue to the next, with a reduction in energy as it travels further from the source. The energy then sets up further vibration of the tissues, and resonance with all its associated effects may result. The main protective mechanisms of the spine are the cartilage and ligament systems, the muscles of the back and the intervertebral discs. However like any other part of the body or a machine they have breaking points, a level or limit where they can no longer offer or provide the level of protection required, and they then allow the energy to reach and damage sensitive areas where pathology can develop.

Figure 1.4 The spine, its vertebrae and curvature.



Source: ILO Encyclopaedia (1998).

Figure 1.5 The basic functional unit of the spine.



Source: ILO Encyclopaedia (1998).

1.3.3 Intervertebral Discs

The intervertebral discs act as cushions to reduce the mechanical energy being transmitted up the spinal column and reducing any damage that energy may cause, however with an increase in the intensities and repetitiveness of vibrational shocks experienced with mechanisation, and the advent of vehicular transportation, coupled with the duration of exposures during a persons working life, damage to the sensitive musculo-skeletal system has increased in frequency and magnitude.

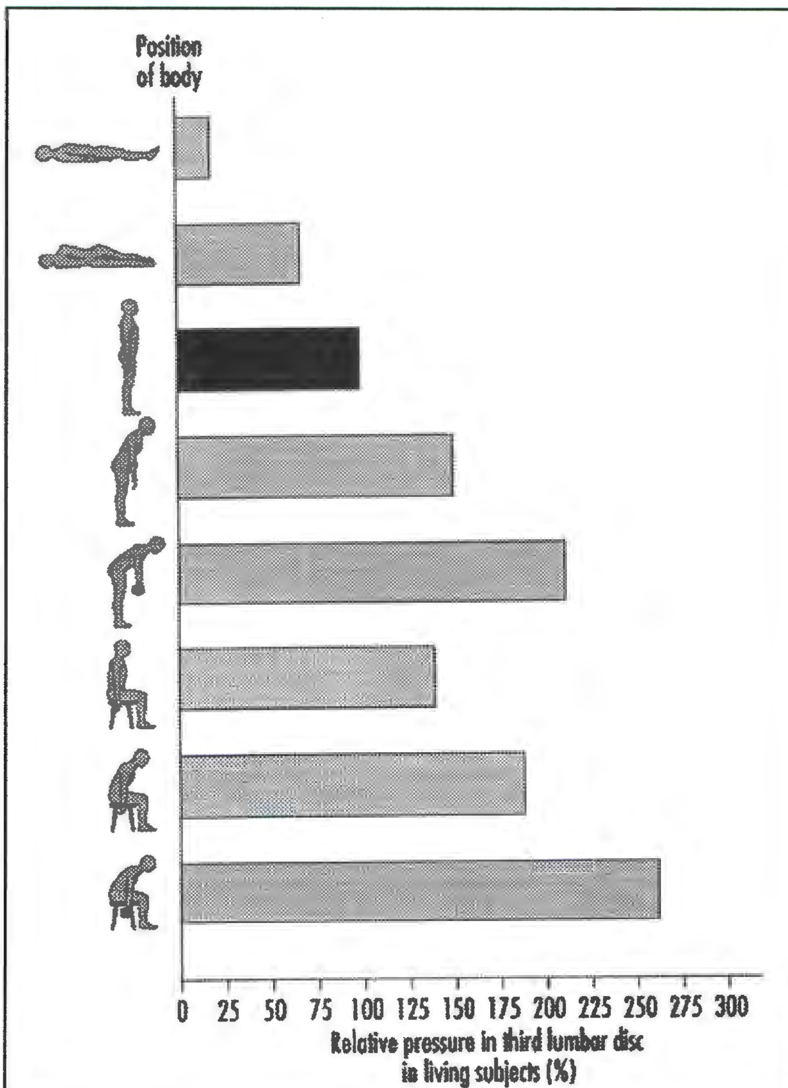
Intervertebral discs are also affected by posture and the transmission of vibration to the spinal column (Grandjean 1990). These discs when placed under pressure such as during exercise, excessive loading or vibrational impact, become flattened and in advanced cases herniated, where the viscous fluid may be squeezed out. The accelerated degenerative process impairs the mechanics of the vertebral column and allow tissues and nerves to be strained and pinched leading to various back problems.

A study by Videman *et al* (1990), studied the pathology of the lumbar spine in some depth in cadaveric material. They studied the occurrence of symmetrical disc degeneration, annular ruptures, end plate defects, vertebral body osteophytosis, and facet joint osteoarthrosis, in 86 male cadavers for whom occupational, physical loading and back pain histories were obtained. The occupations were classified as sedentary, mixed, driving and heavy work, according to selected criteria. There was a positive association between a history of back pain, sciatica and disability from back pain, and occupations involving heavy work and driving. Severe symmetric disc degeneration was clearly related to sedentary occupations and heavy work, whereas annular ruptures seemed to have not been affected by factors such as aging, physical exercise, and the heaviness of physical work, but occurred most frequently in subjects in the driving profession. This study showed a more specific picture of spinal pathology with different occupational groups having different work activities affecting the spinal column in different areas, and ways. Unfortunately this type of investigation clearly cannot be carried out on living subjects.

1.3.4 Nutrition of the Vertebral Discs

The vertebral discs are put under heavy stress when a person remains seated for prolonged periods without significant movement of the spinal column. In one study it has been shown that disc pressure is greater when sitting than when standing and is dependant on the exact posture adopted when driving a vehicle (Nachemson and Elfstrom 1970). In addition, the interior of a disc has no blood supply, and must be fed by diffusion of nutrients through the fibrous outer ring. Kramer (1973), showed that this pressure on the disc creates a diffusion gradient from the interior to the exterior so that tissue fluid leaks out, taking nutrients with it and resulting in increased wear and reduced repair of the cells. This factor alone could lead to increased degeneration of the discs, with associated increases in pain production. Sitting for prolonged periods of driving with constant vibrational shocks on the spinal column would accelerate this phenomenon (Kramer 1973).

Figure 1.7: Relative intra-discal pressures in different postures compared to the pressure in upright standing positions (100%).



Source : ILO Encyclopaedia (1998).

1.3.5 Damage to the Vertebral Body

Many vehicles, including most forklifts, excite the resonant frequencies of the spine causing damage through a cumulative process of micro fractures to the end plates of the vertebral bodies (Burgess-Limerick 1996). The cushioning effects of the inter-vertebral discs often cannot withstand the cumulative shocks and stresses and over time flatten out allowing more vibration energy to be transmitted to the vertebral bodies themselves.

Musch (1990) compared the spinal x-ray examinations of 273 male drivers of earth movers with a minimum exposure duration of 10 years and an average age of 42.8 years with the x-ray images taken at the pre-employment examinations of 324 male workers (mean age 41.4 years). He observed more degenerative changes in the lumbar spine of the driver's compared to the references in each age category. Videman *et al* (1990) however found that end plate defects, osteophytosis of the vertebral body, and facet joint osteoarthrosis were more strongly linked to heavy work than driving.

1.3.6 Electro-Myographical (E.M.G.) Muscular Response and Fatigue

During prolonged driving activities the muscles of the back are placed under stress which is aggravated by the need to maintain balance during vibration, leading to fatigue as static effort causes blood vessels to compress by the internal pressure of the muscle tissues, cutting off the blood flow. This in turn results in a lack of oxygen and glucose, and a build up of lactic acid resulting in acute pain and muscular fatigue (Bongers and Boshuizen1990).

Wasserman *et al* (1997), point out in their editorial, that when a load is added to the extremity muscles, several modifications to the background electromyography (EMG) activity occur representing the compensation for the added load, with the polysynaptic reflex having a latency of 50-80 milliseconds, the triggered reactions have a latency of 80-120 milliseconds and voluntary reaction time having a latency period of 120-180 milliseconds. These will all effect the reaction of the nervous system and muscles to the vibrational stimulus. It is further pointed out by Wasserman *et al* (1997) that patients with chronic back pain are exposed to several additional aggravating factors during sudden loading, and it has been found that the time from load onset to the first detectable erector spinae EMG response is significantly slower in low back pain patients compared to healthy volunteers, thus allowing the load to stress the spinal structures longer. A similar reaction would be expected when vibration exposure occurs and the driver is thrown off balance by a vibrational shock load. It was also found by Wasserman *et al* (1997) that the EMG reaction magnitude was lower, a probable result of the inability of the muscular system to protect the spine adequately from sudden loads. Furthermore reaction tendencies to sudden load were shorter and the forces and moments were larger, thus allowing the larger forces to propagate faster through the multi joint system of the spinal column. These factors indicate that after injury a person is even less able to withstand ongoing vibration exposure, as the body's protection systems react less effectively with increasing exposure and increasing injury.

It has been shown above by Wasserman *et al* (1997) that the shocks and vibrational frequencies experienced during driving cannot be anticipated by the driver. Seated drivers response to the rapidly applied loads on the body can only be reactive, as the demands on the body change faster than the muscles can respond, and the neuro-muscular control systems adaptation to the environment no longer functions properly. Thus, the muscles can only react and those reactions place unnecessary and deleterious loads on the intervertebral discs. The back muscles respond out of phase with the vibratory stimulus and the delay is based on a musculoskeletal response characteristic over which humans have no conscious control. Even if we could voluntarily respond to the vibration, it would still serve only to add load to the spine (Wasserman *et al* 1997). This then leads to the inability of the back muscles to protect the spine from sudden vibrational loads as the muscles react a few milliseconds after the vibrational energy has passed up through the spine. Electromyographic measurements on the back muscles have shown that the higher myoelectric activity provoked by vertical vibration in the most sensitive frequency ranges are far from protective, because the enhanced muscle tension increases the load on the vertebral bodies and discs and cause fatigue and pain. (Seroussi *et al* 1989) At many frequencies, the muscle response is so far out of phase that their forces are added to those of the vibration stimulus (Pope 1993).

Bongers and Boshuizen (1990), however also point out that quantitative estimates of the spinal load based on measurements of EMG back muscle activity may be subject to error due to the test experimental conditions being different from the actual exposure conditions. Nevertheless they point out that it seems justifiable to conclude that the timing of the muscle activity in the back muscles at least determines the load on the spine due to whole-body vibration.

Thus it can be concluded according to the present evidence, that humans are not physiologically suited to this type of exposure, and cannot adapt adequately to the extent needed to offer adequate protection to the spinal column. Other control measures independent of the driver therefore need to be implemented to reduce exposure to vibrational energy. Wasserman *et al* (1997), conclude that time and money would be better spent diagnosing and treating the seated, vibration exposed workplace with the aim of providing optimal back support and maximum attenuation of vibration. The editorial by Wasserman *et al* (1997) warns against the use of the "occupational work hardening" treatment which they likened to the 1900's work cure regimen, for treatment of patients with back pain from whole-body vibration exposed occupational groups. Occupational work hardening is the use of simulated whole-body vibration exposure as a therapeutic "work hardening" modality for returning back injured workers to their jobs.

1.3.7 Back Pain

The relationships between the changes of the spinal system and the symptoms experienced are complex, as pain may arise when no permanent damage has occurred, eg: strained back muscles. In addition structural changes do not always elicit pain symptoms (Bongers and Boshuizen 1990). Most of the evidence to date points to the fact that the pain symptoms caused by whole-body vibration is due to degenerative changes of the spine, with biochemical alterations involving pain related neuropeptides also playing a part .

Bongers and Boshuizen (1990), present some of the possible mechanisms whereby whole-body vibration energy and degenerative changes of the spine are associated with back pain symptoms. These include: 1.) Changes induced by whole-body vibration exposure could render the spine more susceptible to future spinal load; 2.) Damage to one spinal level could increase the load and risk of degenerative changes at other levels, as all spinal motions are coupled; 3.) Whole-body vibration also increases the muscular activity of the back, which may lead to muscular fatigue and pain, increasing the load on the vertebrae and other structures; 4.) Muscular fatigue may enhance structural damage because of increased instability of the vertebral column and whole-body vibration exposure may also aggravate changes originating from other factors.

All of these mechanisms are complex, and not easy to differentiate and diagnose, making the outcome ie: lower-back pain the only tangible symptom felt, of many different pathways.

However if whole-body vibration exposure causes or exacerbates existing symptoms that would otherwise subside, then the exposure is clearly responsible for the work-related back pain. Schilling and Anderrsen (1986), point out that with a clearer understanding of the multiple aetiology of disease through the epidemiological investigation of risk factors, the definition of "work relatedness" has broadened to include diseases in which a variety of work factors may play causative, provocative or aggravating roles. They offer that a broad classification with four categories of work related disease is needed, 1) necessary cause eg: lead poisoning, 2) contributory causal factors eg: stress, 3) latent, provoking or aggravating an established disease eg: eczema and, 4) offers ready accessibility to potential dangers eg: inn keeping -alcoholism. This somewhat blurs the distinction between "work related and environment". This method allows a better determination of disease and injury from all factors for the purpose of overall holistic prevention and management and highlights the importance of attempting to assess as many risk factors as possible both in the occupational environment and non-occupational factors that may be associated with the development of back pain and other musculo-skeletal injuries. It is however also pointed out by Schilling and Anderrsen (1986), that this approach is much more difficult to implement, especially in developing countries.

In one vibration study carried out by Mclain and Weinstein (1994) to "identify ultrastructural changes in dorsal root ganglion neurons consistent with and capable of producing neuropeptide changes, previously documented in vibration exposed animals" it was concluded that ultrastructural changes generated by a physiologically valid vibration stimulus provided an anatomical link between the clinical observation of increased back pain and the biochemical alterations involving pain related neuropeptides. This study managed to relate direct vibration on rabbits to the production of pain in a clinical experiment. This was a significant finding that unlike human studies excluded other variables such as posture, sitting for prolonged periods, occupation, education and socio-economic status. This study showed significant evidence that the changes caused by whole-body vibration exposure produced pain responses in the biological system thereby linking the vibration exposure to specific pain related mechanisms.

1.3.8 Other Health Effects

Other effects mentioned in the literature, but not covered in any great detail, are reports of piles, high blood pressure and kidney disorders amongst drivers (Hendrikse 1996). In a study by Ishitake *et al* (1998), gastric motility was studied in a group of healthy men using cutaneous electrogastrography (EGG) techniques, during and after whole-body vibration exposures, and they concluded that the exposure suppressed gastric contraction and motility activity which may in their opinion lead to gastro-intestinal disorders. However once again they state that definite evidence of dose-effect relationships and the mechanisms of this impairment have not been clarified. Again this shows the lack of knowledge regarding all the potential health effects of whole-body vibration exposure on many parts of the body and its systems.

1.3.9 Conclusion

Many of the mechanisms of damage and effects of vibrational energy on the spinal column and surrounding tissues are not fully understood. The effects most commonly reported by exposed workers is lower back pain, which is a non-specific symptom common to many ailments. From the research evidence to date, Bogadi-Sare (1993) conclude that "The most pronounced long-term effect of whole-body vibration is therefore damage to the spine." Most of the research material we have is inconclusive as to the exact pathological mechanisms that take place, and the other risk factors that are present along with the whole-body vibration exposure make it even more difficult to understand and unravel these relationships.

1.4 REVIEW OF EPIDEMIOLOGICAL WHOLE-BODY VIBRATION AND LOWER-BACK PAIN STUDIES

1.4.1 Introduction

From a review of the existing literature from the early 1960's to the present day, the overwhelming body of evidence points to the fact that exposure to whole-body vibration causes lower-back pain and other associated musculo-skeletal problems, especially in the spinal column and surrounding tissues. However clear dose-response relationships are still unavailable. Many studies have been carried out on many different vibration exposed occupational groups (Bogadi-Sare 1993; Brendstrup and Biering-Sorensen 1987; Futatsuka *et al* 1998; Malchaire *et al* 1996; Pope *et al* 1987 and 1993; Riihimaki *et al* 1989; Wikstrom 1993 and Wilder *et al* 1996), and have examined the evidence for causes of lower-back pain. This review will discuss some epidemiological challenges in assessing back disorder risk factors and then go on to sum up the evidence firstly in relation to studies of whole-body vibration and then for back pain studies.

1.4.2 Musculo-Skeletal Epidemiology

A great challenge that has held back progress in the field of prevention of work-related musculo-skeletal disorders, and created confusion is the lack of quantitative information on the dose-response relationship of back disorders and occupational risk factors, where characterisation of exposures and outcomes (due to yes/no responses) has been difficult to quantify. Burdorf *et al* (1997) points out that most epidemiological studies have presented crude associations between risk factors and back disorders and experience difficulty in controlling for confounders. Risk factors have been determined largely from qualitative data, with poor characterisation of exposure, and health end-points defined as non-specific disorders ie: back pain, sciatica and other non-specific pain, which has resulted in outcome misclassification.

Some of the unique features of musculo-skeletal epidemiology are:

Firstly unlike many hazardous agents in the workplace the nature of the exposure dose-response relationship is complex. Increased intensity and/or duration of whole-body vibration exposure does not necessarily result in an increased effect or severity of disease as would be expected in the classic dose-response relationship. This lack of linear dose-response relationships therefore complicates the prediction of the exact effects the vibration energy on the human body tissues, especially when we take resonance of tissues into consideration.

Secondly health end points of back disorders are usually measured indirectly in terms of a symptomatic state, such as pain, rather than verifiable clinical outcome, such as herniated lumbar disc. This may result in outcome misclassification due to a) the fact that symptoms may not always be reported objectively by patients, b) symptoms are non-specific and may reflect other aetiologies, and c) symptoms may be culturally specific. Bongers and Boshuizen (1990) mentioned that a complicating factor in diagnosing back disorders is that one type of damage to the spine may lead to other effects, such as neural damage from a herniated disc. Diagnostic methods used apart from symptoms, are mainly based on x-ray imaging, and the association between back pain and damage seen on roentgenograms of the spine is usually weak, possibly because important forms of damage (eg: soft tissue damage) escape discovery on x-rays.Damage is seen on x-rays in symptomless individuals, and therefore most x-ray signs have limited practical relevance and poor sensitivity and specificity. The use of x-rays is also now considered unethical for non-clinical use. It can thus be concluded that symptoms are much more relevant although subjective and have their own short comings.

Burdorf *et al* (1997) go on to point out that unfortunately the most non-specific outcome ie; lower-back pain, is also the most common. The non-specificity of pain as a health end point is a major drawback, and back pain could relate from a range of causes from minor muscular sprains, to intervertebral disc damage or even to an entirely different disease such as lung cancer, which is another example of outcome misclassification.

Thirdly there is little knowledge of the natural disease process where minor ailments progress to severely disabling back disorders. Back pain will affect nearly everyone at some point in life, and the vast majority of pain episodes will recover in a few weeks without treatment. In epidemiological studies, it is difficult to define the time of onset of back disorders and to distinguish incidence and recurrence of back disorders, so differentiation between chronic and acute pain symptoms are difficult.

Burdorf *et al* (1997) conclude by saying the main challenge is to design epidemiological studies that address all the main risk factors in order to study their relative contribution to the occurrence of back disorders.

1.4.3 Review of Vibration Studies

Numerous back pain studies have been carried out around the world that attempted to clarify the relationships between whole-body vibration exposure and the development of back pain. Many different professional driving occupational groups have been studied by the researchers in this attempt and a selection of some of these studies is shown in table 1.2 below.

Table 1.2: Summarised whole-body vibration studies conducted on forklift drivers and other occupational groups, their main findings and measurement instruments used.

Authors Name (Date)	Study Population	Sample Size (reference group)	Main Findings	Comments
Bovenzi (1996)	Bus drivers	436 (240)	Lifetime prevalence of LBP 83.8% for drivers, and 66.4% for controls. Found trends of increased LBP with increased total vibration dose.	Used modified Nordic Questionnaire. Possible selection bias due to drivers leaving before follow-up period.
Boshuizen, Bongers and Hulshof (1990)	Forklifts and Freight Container Tractor Drivers	242 (210)	68% prevalence of LBP in drivers versus 25% in reference group. Drivers more prone to developing LBP in first 5 years of driving. WBV RMS values 0.8m/s-2 for forklifts and 1.0m/s-2 for freight container trucks.	Difficulty in establishing doe-response relationship. Used Nordic questionnaire.
Bongers, Boshuizen and Huslhof (1990)	Wheel Loaders	47 (52)	Prevalence of LBP in drivers 54%, and 44% in reference group. Prevalence of LBP increased with increased WBV dose after adjusting for age. WBV RMS value 0.5m/s-2	Used Nordic questionnaire.
Riihimaki *et al* (1989)	Longshoreman and earth movers	541 (695) 331 (674)	Prevalence of LBP in all three groups high (90%). Machine operators reported more 12 month prevalence (82% versus 62%)	Used modified Nordic Questionnaire.
Brendstrup and Biering-Sorensen (1987)	Forklift Drivers	240 (359)	Significantly higher occurrence of LBP and absenteeism in forklift drivers compared to reference group.	Never used Standardised questionnaire.

Hulshof and Van Zanten (1987), reviewed 19 vibration epidemiological studies from the early 1960's through to 1984, using evaluation criteria that looked at vibration exposure, health effects, and methodological rigour for each study. These studies covered many different occupationally exposed groups that were classified into four main categories, agriculture, construction industry, transportation, and aviation. In those early studies, due to methodological faults, as well as the quality and quantity of the exposure data available, the conclusion was that the existing epidemiological literature at the time was not very informative in assessing the evidence of an association between whole-body vibration and the reported effects. Most of the studies were cross-sectional which when compared to a longitudinal study design (cohort and case control) have a lower validity from which to infer causality.

Their main findings and recommendations regarding these early studies, was that priority should be given to study design and statistical analysis, and they recommended retrospective cohort and case-control studies. However they also mentioned that intervention trials and prospective studies permit even more valid conclusions, but these were neither feasible nor cost effective in their opinion. The authors went on to say that the use of an adequate internal or external control group and adjustments for possible confounding factors such as age, sex, socio-economic status and particularly working posture was very important and could not be over-emphasised. Riihimaki and Tola (1989), (see table 1.2 above),make reference to the fact that education and social status are related to many lifestyle factors that may affect the occurrence of lower-back pain, and in general low-back pain has been found to be more common in the lower than the higher social classes. This factor needs to be taken into account when selecting a control group for comparison to an exposed group, and the practice of selecting other sedentary groups for comparison from office or administrative occupational groups should be avoided.

Hulshof and Van Zanten (1987), also pointed out that many of the studies had not presented information on vibration measurement, and if they did, many were not measuring vibration according to ISO guidelines, which are standardised protocols for measurement and evaluation of whole-body vibration exposure of humans.

However in their findings Hulshof and Van Zanten (1987), concluded that because almost all findings in the different studies reviewed, showed a strong tendency in a similar direction, viz: that long term exposure to whole-body vibration is harmful to the spinal system, and may result in lower-back pain, early degeneration of the spine and herniated discs. However based on the available epidemiological data. firm conclusions on exposure-response relationships could not be drawn.

Bovenzi and Hulshof (1998), carried out an updated review of epidemiological studies on the relationship between exposure to whole-body vibration and low back pain, when they reviewed 37 studies published between 1986 and 1996. Of these 37 studies, a total of 16 satisfied the selection criteria, that included whole-body vibration exposure, assessment of health effects and methodology.

These 16 studies reported the occurrence of lower-back pain in 19 whole-body vibration exposed groups ranging from drivers of buses, forklifts, tractors, cranes and subway trains, to helicopter pilots, and included 13 cross-sectional study designs, 5 longitudinal designs, and only one case-control design.

Their first conclusion was that after analysing the articles, the epidemiological study data including the research designs and the quality of exposure and health effect data had improved in the last decade as compared to the previous studies reviewed before 1986.

All the studies included had used the standardised method, ISO 2631-1985, for vibration measurements on the vehicles which allows comparison of data. In most of these studies for the assessment of health effects, the investigators used predominantly medical interview or questionnaires identical or similar to the standardised Nordic Questionnaire on Musculo-skeletal symptoms (Kuorinka *et al*, 1997).

The findings of both the cross-sectional, (pooled prevalence odds ratio POR 1.5; 95% CI 0.9-2.4) and cohort epidemiological studies (age-adjusted incidence density ratio IDR 1.8; 95% CI 1.1-3.1) indicated that there is an increase risk for lower-back pain disorders among occupational groups exposed to whole-body vibration when compared to non-exposed control groups.

Table 1.3: Assessment criteria used to evaluate epidemiological studies by Bovenzi and Hulshof, 1998.

1.Assessment of Vibration Exposure
-measurement according to guidelines of ISO 2631-1
-duration of exposure (subjective or Objective methods)
2.Assessment of Health Effects
-lower back pain/sciatica (self reported questionnaire, medical interview, health statistics)
3.Methodology
- study design (cohort, case-control, cross sectional with control group/without control group)
- selection of study population (absence of healthy worker effect, response rate)
- description of potential confounders (age, smoking, education, manual handling, bending and twisting, heavy physical work, job dissatisfaction and low decision latitude)
- control for potential confounders/other risk factors in study design or analysis (age, smoking, education, manual handling, bending and twisting, heavy physical work, job dissatisfaction, and low decision latitude)

Source: Bovenzi and Hulshof (1998).

A similar review of whole-body vibration studies was carried out by Boshuizen, Bongers and Hulshof (1990), (see table 1.3), that reviewed 74 studies conducted over a period ranging from 1966 to 1990, included many vibration exposed occupational groups, such as the groups mentioned above plus tank drivers, Grand Prix drivers, and car drivers. 31 of these studies were excluded from the meta-analysis, due to inadequacies in data provide, methodology or absence of reference or control groups.

Their conclusion after meta-analysis was that low-back pain is clearly increased in workers exposed to whole-body vibration, (pooled OR: 1.53; 95% CI: 1.32-1.78) and drivers of vibrating vehicles, and helicopter pilots have more degenerative disorders of the spine (pooled OR: 1.5; 95% CI: 0.9-2.0). They also went on to say that the effects observed at that time, may partly have been due to other possible risk factors in the occupation. Whether these factors act independently (confounders) or in combination (effect modifiers) with the whole-body vibration could not be concluded at that time from the epidemiological studies carried out.

The multifactorial and probabilistic nature of most exposure-disease relationships implies that disentangling the role played by one specific exposure is problematic. In additional the observational nature of epidemiology prevents us from conducting experiments that could clarify aetiological relationships through wilful alteration of the course of events. The observation of a statistical association between exposure and disease does not mean that the association is causal. Given the probabilistic-multifactorial nature of most exposure-disease associations, epidemiologists have developed guidelines to recognise relationships that are likely to be causal. These guidelines were originally proposed by Sir Bradford Hill in 1965 for chronic diseases. These criteria should be considered only as general guidelines or practical tools; in fact, scientific causal assessment is an iterative process centred around measurement of the exposure-disease relationship. However, Hill's criteria often are used as a concise and practical description of causal inference procedures in epidemiology (ILO, 1998).

In principle, causality of association requires evidence on the strength of association, consistency in findings, biological plausibility, temporal sequence of risk and effect, dose-response gradient, specificity of risk factor for the health outcome, and coherence of evidence, (Hill, 1965). Many of these factors can be satisfied with regards to whole-body vibration exposure and lower-back pain in varying degrees, but as Burdorf and Sorock (1997) point out, it is obvious that all these criteria cannot be fulfilled satisfactorily for all risk factors in all studies. The criterion on temporality calls for cohort studies which are not commonly encountered in the study of the epidemiology of musculo-skeletal disorders. Although proof of reversibility makes a very strong case for a particular risk factor, intervention studies on work-related risk factors for back disorders that show a decrease in the occurrence of back disorders after ergonomic improvement are very scarce.

Table 1.4: Bradford Hill Criteria applied as a description of the possible causal inference relationships of lower back pain epidemiology.

Strength of Association	YES	With increase in Relative Risk.
Consistency of Findings	YES	Many studies have shown similarities
Biological Plausibility	YES	Strong association with LBP
Temporal Sequence of Risk and Effect	YES	Exposure Precedes Effect, but LBP may be associated with other causes.
Dose-Response Gradient	NO	No Clear Association
Specificity of Risk Factor for Outcome	YES/NO	LBP and various musculo-skeletal disorders difficult to associate with specific cause/exposure.
Coherence of the Evidence	YES	Coherence with biological background and previous knowledge.

Source: Hill (1965).

From the foregoing evidence it can be reasonably inferred that prolonged whole-body vibration exposure while operating a vehicle shows some evidence that it causes lower-back pain and other musculo-skeletal changes in the spinal column of exposed operators.

1.4.4 Review of Back Pain Studies

Many studies have been carried out with back pain as the main focus, examining potential risk factors. Most people will have back pain at some stage in their lives, but this is transient in nature and eventually goes away. However many occupations and exposure situations can in fact cause back injuries and back pain that becomes permanent and disabling to the person, radically affecting their lives. Some of these studies and the evidence presented will be discussed and critically analysed for an insight into methodological and other considerations when dealing with lower-back pain research studies..

In a structured review of studies of the prevalence of low-back pain in 26 Nordic Studies carried out between 1954 and 1993, Leboeuf-Yde and Lauritsen (1995) found that outcomes for low-back pain were characterised most commonly through questionnaires. However at that stage many studies used questionnaires they developed themselves which did not allow for easy pooling and/or comparability of data. They suggested that standardised and tested questionnaires be used such as the standardised Nordic Questionnaire for musculo-skeletal symptoms (Kuorinka *et al* 1987). They also reported that there was a lack of research implementation, where the results are used to implement changes that can be re-tested after a suitable time period. Their main conclusions were that at that time there were large differences between studies on back pain, and that a more stringent, systematic and uniform methodological approach to studying the prevalence (or incidence) of back pain was needed. Eleven methodological criteria were given by Leboeuf-Yde and Lauritsen (1995), under three main categories.

Table 1.5: Methodological criteria used by Leboeuf-Yde and Lauritsen (1995) to review Nordic low-back pain studies.

1.Final Sample Representative of Target Population - at least one of the following:	
-	Whole-target population, randomly selected or representative sample.
-	Reasons for non-response described, or comparison of respondents and non-respondents
-	Response rates stated
2.Quality of Data	
-	Primary lower-back pain data
-	Same mode of data collection for all subjects
-	Questionnaire validated, tested for reproducibility
-	Interview validated, or performed by the same person
-	Medical examination tested and validated
3.Definition of Lower-back Pain Problem	
-	Precise anatomical delineation of lumbar area
-	Question put to subject quoted
-	Recall periods clearly stated eg: 1 month, lifetime etc

Source: Leboeuf-Yde and Lauritsen (1995).

Burdorf and Sorock (1997), carried out a review of 35 studies conducted over period of 15 years, in order to identify consistent risk factors for back disorders and to determine the strength of association between the two. These risk factors included lifting or carrying loads, whole-body vibration, and frequent bending and twisting, found to be consistently associated with work-related back disorders. They started off with 140 studies and used criteria to exclude any study that did not meet the following requirements: 1.) Inclusion of quantitative information on work related risk factors; 2.) Sufficient information that allowed calculations of risk estimates; and 3.) The appropriateness of study methodology in relation to the particular purpose of the review. Thirteen of the studies included in the review were vibration studies and the overall conclusion was that whole-body vibration consistently showed positive significant associations with back disorders. Other activities such as heavy physical load and frequent bending and twisting were also shown to increase the risk of back disorders.

Most of the studies reviewed by Burdorf and Sorock (1997), used a questionnaire (partly) based on the Nordic questionnaire on musculo-skeletal symptoms, and they reported the validity of this questionnaire is sufficiently high to warrant its application in epidemiological studies. The questionnaire structure and use will be discussed later in more detail in section 1.5.2.

As far as measurement of health outcome and exposure go, Burdorf and Sorock (1997) found that the main description of the health outcome included low-back pain, back trouble, chronic back pain, and sciatica. Earlier studies had problems with the standardisation of how lower back pain was defined leading to problems with comparison or combining of results between studies.

1.4.5 Conclusion

From the evidence of the review of the epidemiological whole-body vibration and lower back pain studies, it can be seen that most of the literature is very consistent with the average odds ratio showing a +-50% increase in the risk when back pain or lower back pain are considered with vibration exposure. A 50% increase in risk or odds of getting back pain when exposed to whole-body vibration and related factors may seem to have moderate implications for the workforce when other industrial hazards are considered. However when we take into account the high prevalence of exposure with an estimated forklift driver population in South Africa of 60 -

70 000 (De Klerk, 2000), we can see that the even a moderate increase in the odds ratio affects many people and therefore has a high population attributable risk, and indicates that whole-body vibration is an important occupational hazard that needs to be controlled.

1.5 MEASUREMENT INSTRUMENTS FOR BACK PAIN IN EPIDEMIOLOGICAL STUDIES

1.5.1 Use of Questionnaires as a Measurement Instrument

As has been mentioned earlier, most studies dealing with back disorders, and whole-body and other types of exposure, used some type of questionnaire to elicit the responses from the study subjects. These questionnaires gathered important information regarding the actual personal characteristics of the respondents, working conditions, risk factors, exposure characterisation, as well as the incidence/prevalence and severity of pain related to musculo-skeletal symptoms and disorders.

One of the shortcomings of some early studies was the lack of standardisation in the questionnaires as discussed by Leboeuf-Yde and Lauritsen (1995), that did not allow for pooling and comparison of data. It also brought into question the validity and reliability issues that are important in any study and particularly relevant for back pain studies..

1.5.2 The Standardised Nordic Questionnaire for Musculo-Skeletal Disorders

In 1987, a standardised Nordic questionnaire was developed based on other standardised medical questionnaires, by Kuorinka *et al* (1987), to allow some standardisation and a basis for adapted questionnaires to be developed to suit the different occupational settings where these types of studies were to be carried out.

The Nordic questionnaire consists of structured, forced, binary or multiple choice variants and can be used as a self administered questionnaire or in interviews. It appears useful both as a clinical screening tool and as a research instrument.

The questionnaire, concentrated on an a specific anatomical area, ie; the lower back, and the questions probed more deeply into the analysis of the respective symptoms and elicited responses on the duration of the symptoms over past time ie; entire life, last 12 months, and previous 7 days. The main usefulness of these questions according to Kuorinka *et al* (1987), is that they analyse more thoroughly the severity of the symptoms in terms of their effect on activity at work and during leisure time, and in terms of total duration of symptoms and sick leave during the preceding 12 months.

This type of interpretation is not very clear, in the opinion of the author as the interpretation of findings regarding severity of back pain from the questionnaire is inferred from the length of time the pain lasts after the work activity ceases, such as when driving stops at the end of a shift. Severity is not assessed from a question directly asked regarding the pain or rating of the pain. Burdorf and Sorock (1997), in their review article criticised the standardised Nordic questionnaire in that it does not allow proper differentiation of symptoms according to type, severity and frequency. Hence it is difficult to distinguish persons with chronic, persistent back pain from those who's back pain is an isolated or insignificant event. A further more specific severity rating scale was thus needed.

The Nordic questionnaires, have up till 1987 been used in more than 100 different studies, as well as routine work in occupational health care services and administered to more than 50 000 people. The reliability and validity have been investigated, through repeat questionnaires, and by comparison of subjects responses to their clinical histories. One study as reported by Kuorinka *et al* (1987), involving safety engineers and medical secretaries showed the number of non-identical answers varied from 0 -23%, a validity test against clinical history showed the number of non-identical answers varied between 0 and 20%. These tests were also used to test validity and reliability of questions for reformulation in the final versions. The authors of the questionnaire did not cite kappa statistics, which is the norm for assessing test-retest agreement of an instrument such as a questionnaire on categorical data. Kappa measures the amount of agreement beyond chance, and this factor should be considered when compiling questionnaires of this nature.

In the final conclusion of the Nordic group, they were of the opinion that the questionnaires provided a useful and reliable source of information on musculoskeletal symptoms, that can be used to identify subjects needing further in-depth investigation, or to aid decision making on preventive measures.

1.5.3 The 101-Point Numerical Rating Scale

The author decided to further investigate in order to refine the questionnaire in this study using a more specific and accurate severity rating scale. The one selected is known as the 101-point Numerical Rating Scale (NRS-101), as discussed by Jensen, Faroly and Braver (1986) in a study they conducted that investigated the measurement of clinical pain intensity by a comparison of six methods. They assessed several scales commonly in use including the Visual Analogue Scale, an 11 Point Box Scale, a 6 Point Behavioural Rating Scale, a 4 Point Verbal Rating Scale, a 5 Point Verbal Rating Scale and the 101 Point Numerical Rating Scale. These scales all assessed subjective intensity to pain, the most commonly measured outcome in both clinical work and in treatment outcome research.

The authors used five criteria for judging the intensity scales, including ease of administration and scoring, relative rates of incorrect responding, sensitivity as defined by the number of available response categories i.e. number of choices for response, sensitivity as defined by statistical power and the magnitude of the relationship between each scale and a linear combination of pain intensity indices.

The NRS-101 scale consists of asking the respondent to rate his or her perceived level of pain intensity on a numerical scale from 0 to 100, with 0 representing one extreme (eg: no pain), and the 100 representing the other extreme (eg: pain as bad as it could be). The number stated by the respondent as representing the level of pain intensity is the basic datum for the NRS-101 scale.

Jensen, Faroly and Braver (1986), commented that the NRS-101 was one of three scales that were extremely simple to administer and score, and the NRS-101 scale offers greater room for variability of response categories. They concluded that the NRS-101 scale has several practical advantages over the others.

Table 1.6: Six Pain Intensity Measures Reviewed by Jensen, Karoly and Braver (1986).

THE VISUAL ANALOGUE SCALE (VAS)

No Pain --Pain as bad as it could be.

THE 101 - POINT NUMERICAL RATING SCALE (NRS-101)

Please indicate on the line below the number between 0 and 100 that best describes your pain. A zero (0) would mean "No pain", and a one hundred (100) would mean "Pain as bad as it could be". Please write only one number.

0--100

THE 11 - POINT BOX SCALE (BS-11)

If a zero (0) means "No pain", and a ten (10) means "Pain as bad as it could be", on this scale of zero (0) to ten (10), what is your level of pain? Put an "X" through that number.

THE 6 - POINT BEHAVIOURAL RATING SCALE (BRS-6)

(1) No Pain
(2) Pain present but can easily be ignored
(3) Pain present, cannot be ignored, but does not interfere with every day activities
(4) Pain present, cannot be ignored, interferes with concentration
(5) Pain present, cannot be ignored, interferes with all tasks except taking care of basic needs
(6) Pain present, cannot be ignored, rest or bed rest required

THE 4 - POINT VERBAL RATING SCALE (VRS-4)

(1) No pain
(2) Some pain
(3) Considerable pain
(4) Pain which could not be more severe

THE 5 - POINT VERBAL RATING SCALE (VRS-5)

(1) Mild
(2) Discomforting
(3) Distressing
(4) Horrible
(5) Excruciating

Source: Jensen, Karoly, Braver (1986).

1.5.4 Conclusion

The questionnaire as an epidemiological tool of measurement for musculo-skeletal conditions and whole-body vibration exposed groups is very important when collecting relevant data for investigation of the causes and natural history of all types of disease and medical conditions including back pain and other musculo-skeletal disorders, from groups of individuals (population or samples) such as professional drivers or other specific occupational groups. It is a valuable method for the development and evaluation of preventive programmes, as well as the assessment of treatment or interventions and the planning of health services (Farmer and Miller 1983).

Great care has to be taken when designing a questionnaire in order to ensure valid, accurate and reliable information is obtained in order to make sure the aims and objectives of a study are reached. This not only ensures that relevant epidemiological risk factors and causes are evaluated, but also the outcomes of interventions. It allows for standardisation and comparison with other relevant data and studies. The standardised Nordic Questionnaire for Musculo-skeletal injuries is one of these useful tools that can be adapted to suit local conditions and circumastances and should be used as a valuable tool in this type of research.

1.6 INTERNATIONAL VIBRATION EXPOSURE STANDARDS AND GUIDELINES

1.6.1 Introduction

Research into whole-body vibration exposure and control abroad is very far advanced and has been investigated and addressed for many years, with research into many aspects of the hazard and its control. European countries have used the International Standardisation Organisations Guideline (ISO) 2631 titled, "Guide for the Evaluation of Human Exposure to Whole Body Vibration", for the evaluation of Whole-Body vibration and exposure standards, and this has become the standard used by private occupational health and safety inspection authorities approved by the department of labour in South Africa to conduct whole-body vibration measurements. This however has not been legislated or laid down in any regulations, as whole-body vibration is not mentioned specifically in any section of the occupational health and safety legislation in South Africa. A recent update to the ISO guideline 2631 was brought out in 1997, with some changes to the measurement and evaluation of whole-body vibration, this will be discussed in more detail later.

In 1995 the European Economic Community (EEC) released the Whole-Body Vibration Acceptance criteria in which the Machinery Directive now forces manufacturers of heavy equipment and vehicles to design their products to reduce the risks associated with excessive vibration, and make this information readily available to customers and users. The equipment must be tested and certified before it can be sold within the European Union. In the United Kingdom, the British Standard Guide to Measurement and Evaluation of Human Exposure to Whole-Body Mechanical Vibration and Repeated Shock (BS-6841-1987) is used as a standard for the measurement and evaluation, and gives methods for quantifying vibration and repeated shocks in relation to human health, interference with activities, discomfort, the probability of vibration perception and the incidence of motion sickness. Vibration limits are not however presented.

In the United States of America, the American National Standards Institute (ANSI) published a guide in 1979, titled "Guide for the Evaluation of Human Exposure to Whole -Body Vibration", and the American Conference of Governmental Industrial Hygienists (ACGIH), in 1995 incorporated whole body vibration exposure into their annual recommended guidelines publication titled "Threshold Limit Values (TLV's) and Biological Exposure Indices".

Most of the published standards are guidelines and cannot be taken as the boundary above which dangerous levels are defined, this is again due to the difficulties in ascertaining the dose-response relationship of whole-body vibration exposure.

1.6.2 Setting of "Exposure Limits?"

Experimental data collected over the years, for defining limits of vibration exposure to human beings, have resulted in a set of vibration criteria specifically in the ISO standard 2631. This was first brought out in 1974, and revised in 1978, 1985 and most recently in 1997 in an attempt to consolidate the growing body of research on the large number of parameters involved in whole-body vibration measurement (i.e. mechanical, biological and psychological).The standards and guidelines concerning whole-body vibration are designed to reduce vibration to a level where most workers can perform job tasks without discomfort.

The early versions of the ISO guidelines, gave three different types of exposure limits, namely:

- a reduced comfort boundary;
- the fatigue-decreased proficiency boundary; and
- an exposure limit.

The reduced-comfort boundary was for the comfort of people travelling in aeroplanes, boats and trains, and exceeding these exposure limits would make it difficult for passengers to eat, read or write when travelling. This did not relate to occupational exposure situations where work was being conducted.

The fatigue-decreased proficiency boundary was a limit set for time dependant effects that impair performance. For example fatigue impairs performance when operating a vehicle.

The third limit, the exposure limit was used to assess the maximum possible exposure allowed for whole-body vibration. A separate set of "severe discomfort boundaries" was also given for 8-hour, 2-hour, and 30 minute exposures to whole-body vibration in the 0.1 Hz to 0.63 Hz ranges.

These exposure limits were given as acceleration for one third octave band frequencies and the three directions of exposure, ie: X, Y, Z. The exposure limit was lowest for frequencies between 4 and 8 Hz as the human body is thought to be most sensitive to whole-body vibration and resonance at these frequencies.

The "exposure limits" were however meant to be considered as guidelines in controlling exposure, and were not meant to be considered as upper safe limits of exposure, as for example Occupational Exposure Limits (OEL) or Threshold Limit Values (TLV) are for chemical exposures. Nor could they be considered to be a boundary between safe and harmful levels.

The new revised ISO-2631 (1997) guideline document has various changes that incorporates new experience and research results that were reported in the literature, which made it more desirable to re-organise parts of the guidelines, change the method of measurement and analysis of the vibration environment and change the approach to the application of the results. The frequency ranges in the revised version have been extended below 1 Hz, and the evaluation is based on frequency weighting of the RMS acceleration rather than the rating method used before. Different frequency weighting are given for the evaluation of different effects.

Based on practical experience RMS accelerations continue to be the basis for measurements especially for crest factors less than 9 which help to define the roughness of the ride experienced by the ratio of the weighted peak acceleration level to its corresponding weighted RMS value. Consequently the integrity of existing vibration databases is maintained even with the introduction of the new methods. ISO -2631 (1997) points out that studies in recent years have identified the importance of the peak values of acceleration in the vibration exposure in relation to health effects. The RMS method of assessing vibration has been shown by several laboratories to under-estimate the effects for vibration that has substantial peaks. Additional and/or alternative measurement procedures are presented for vibration with these high peaks, and particularly for crest factors greater than 9, while the RMS method is extended to crest factors less than or equal to 9.

For simplicity the dependancy on exposure duration of the various effects on people had been assumed in ISO-2631 (1985) to be the same for the different effects (health, working proficiency and comfort). This concept was not supported by research results in the laboratory and consequently was removed from the 1997 guideline. Exposure boundaries or limits are also not included and the concept of "fatigue-decreased proficiency" due to vibration exposure has also been deleted.

The International Standardisation Organisation asserts that in spite of these changes, improvements and refinements, the majority of reports or research studies indicate that the guidance and exposure boundaries recommended in the ISO-2631 (1985), were safe and preventive of undesirable effects. The revision in 1997, should according to them not affect the integrity and continuity of existing data bases and should support the collection of better data as the basis for the various dose-effect relationships. The United States of America, National Standards Institute (ANSI), guideline for the evaluation of human exposure to whole-body vibration, was taken directly from and based upon the ISO guidelines.

1.6.3 Conclusion

Standardisation is imperative when measurement and evaluation of whole-body vibration is undertaken, not only to ensure that the results are valid and reliable, but to allow a greater degree of comparability between different studies and results. In so doing a database of information can be built up and added to over time enabling a better and more useful picture to develop of the characteristics of vibration exposure and effects, and to allow for advancement of the field and standardised guidelines such as the ISO-2631 document. However care must be taken to ensure that changes are fully tested and acceptable before the changes are made in order to allow continuity and comparability of the old and new. Some criticism has been levelled at the new ISO-2631 (1997) guidance document, where shortcomings and areas open for misinterpretation are pointed out, for example by Griffin (1998), who points out that considerations should be given to the apparent contradictions suggesting that some exposures to whole-body vibration may be acceptable even though the same conditions would be considered unacceptable for hand transmitted vibration, when compared to hand-arm vibration standards. This is a debate that will continue and may result in a revision of either two of the guidelines, the whole-body vibration and/or the hand-arm guidance documents.

1.7 HAZARDS ASSOCIATED WITH DRIVING AND INDUSTRIAL VEHICLES.

1.7.1 Introduction

One of the fundamentals of good ergonomic practice consists of fitting the job to the worker, and ensuring that the design of an occupational environment, such as a vehicle like a forklift, does not require excessive strain, awkward postures or physical and psychological stresses being placed on the human operator that exceed his or her physical and mental capabilities. If so the human machine will break down just as any mechanical machine that has operational limits and capabilities.

Unfortunately this theoretical concept has not always carried through successfully into the engineering and design arena for forklifts and other industrial vehicles. When one considers the research and development for example that goes into the design of a new car, in which the average person spends less that two hours a day driving, many forklift and other industrial vehicles, especially the older types, fall far short in respect of appropriate ergonomic design. The older types of seating provided in a large number of these vehicles are archaic and barely functional from an ergonomic point of view, merely offering a place to perch the driver and not taking any account of his comfort or protection from vibrational energy over extended work shifts and exposure periods.

Table 1.7: Risk factors associated with professional driving [3]

VEHICLES	Seat Design and Ergonomic Defects
	Tyres
	Engine and Vehicular Produced Vibration
ENVIRONMENTAL FACTORS	Driving Speeds
	Loads Carried
	Driving Surfaces
DRIVERS	Posture and Sedentary Jobs
	Work Shifts
	Vibration Exposure

1.7.2 Vehicle Design Considerations

1.7.2.1 Seat Designs and Ergonomic Defects

Many of these inadequately designed seats are in use in South Africa today where many drivers work for up to 12 hours per shift driving. Some seats are bolted directly to the body of the vehicle, offering limited lumbar support, and the only protection against vibration is a foam rubber seat cover, which results in direct transmission of vibration to the spine of the driver. Some newer vehicles have seats of a better design, but for vibration control and dampening some rely on operator adjustment for weight, and damping before driving. This is hardly ever carried out in practice due to lack of knowledge and training amongst drivers, as well as the problems of illiteracy, where a driver will not know his weight and then be able to make the appropriate adjustment to the seat. The seats that rely on air suspension/shock absorbers for damping need to be maintained and the shock absorbers replaced regularly when worn, but usually this is neglected in deference to keeping the vehicle on the road.

A study conducted by Futatsuka *et al* (1998), evaluated whole-body vibration on the seats of ten different types of agricultural vehicles used in Japan, to test the vibration damping effectiveness of the seats and their ability to offer protection to the operators against whole-body vibration.

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[3] **Sources:** Futatsuka *et al*, 1998, Ishikawa, 1998, Burdorf and Swuste, 1993, Wilder *et al*, 1996, Malchaire *et al*, 1996, Brendstrup and Biering-Sorensen, 1987, Burdorf and Sorock, 1997, Grandjean, 1990, Riihimaki, 1989, and Wikstrom, 1993.

They found that seven of the ten vehicles exceeded the European Commission's recommended limit of 0.5 ms^{-2}. and that for most of the vehicles the drivers should not be allowed to drive the vehicles for 8 hours under current vibration exposure conditions. They concluded overall that it was clear that new suspension mechanisms or new vibration reduction mechanisms for agricultural vehicles need to be developed, and work-rest schedules need to be implemented for agricultural drivers.

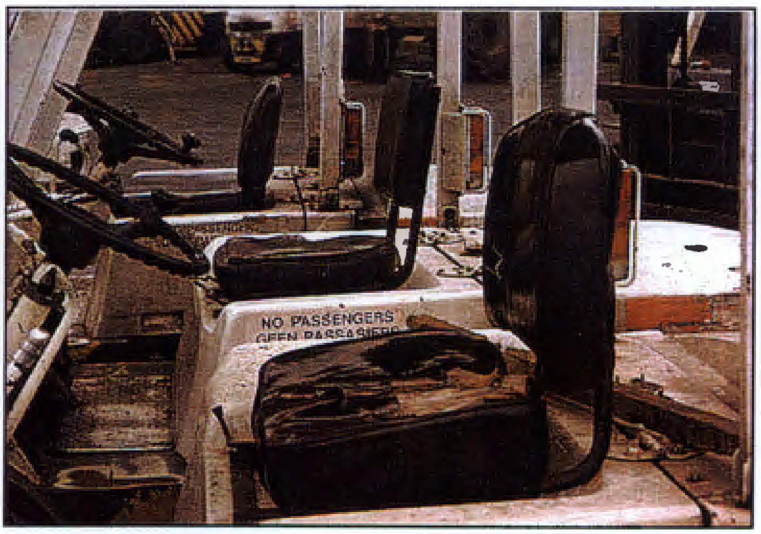
Further to these findings another Japanese researcher, Ishikawa (1998), carried out laboratory experiments to develop a vibration protection seat for agricultural machinery, and managed to reduce the vibration transmissibility of his experimental seats to 25% ie: 75% of the vibrational energy entering the seat at the bottom was absorbed or dampened by the seat, therefore offering a measure of protection to the driver.

Certain factors and conditions in the operating environment and the seat design can in fact have a reverse effect, where the vibrational energy is not attenuated but increased and amplified as it travels through the seat structure from the vehicle chassis to the exposed driver. These are known as seat transmissibility factors. These values may be as a result of some shock loads, especially under rough operational conditions where potholes exist in the driving surface. The most likely cause however is the condition and design of the seat. In a study by Burdorf and Swuste (1993), where they tested 11 suspended seats under laboratory conditions and actual workplace conditions, they found that in general the value of seat transmissibility obtained in the laboratory was lower than that obtained at the workplace and that only 71% of the measurements in their study showed a seat transmissibility factor lower than 100% ie: damping of the vibration. They therefore came to the conclusion after also reviewing the results of four other studies that the damping of vibration provided by many seats of the vehicles studied was poor. They also concluded that most suspended seats do not effectively damp vibration to safe levels as defined in the ISO-2631 standards, and they added that suspended seats need to be evaluated and maintained in order to offer any degree of protection to the driver. They point out that in many working conditions with a daily exposure of eight hours or more suspended seats will not protect professional drivers from harmful exposure to whole-body vibration.

Wilder, Pope, and Magnusson (1996), give an indication of the etiology of the seated vibration environment and the importance of good ergonomic seating design and vibration damping. They say firstly that sitting flattens the lumbar lordosis and shifts the line of force of the spine to a point posterior to the ischial tuberosities, and this may induce an additional rocking motion in the pelvis and may amplify the vibration motion transmitted to the spine. Sitting increases the posterior disc height, and may strain the posterior collagen fibres of the annulus fibrosis, where they are thinner and fewer in number. Lumbar intra discal pressures are significantly greater in the seated posture, which has a tensioning effect on the collagen fibres. Ligaments have been shown to become softer and weaker due to vibrational loading. The resonance frequencies of the spine are close to those produced by a vehicle in motion, and this causes more risk of failure of the spinal structures as a structure vibrating at its resonance frequency is more likely to fail. They also point out that the evidence has shown that there is a risk associated with unexpected loads that can occur during unexpected vertical or horizontal shocks during driving. They go on to suggest that not only improvements in vibration damping mechanisms are needed to reduce the vibration magnitudes, but improvements in seat configurations are also necessary, such as increasing the thigh-trunk angle with an adjustable seat back, and supporting the lumbar curve with a lumbar support, to reduce the intervertebral disc pressure and the strain on the posterior disc. Seat design considerations will be discussed in more detail later.

Plate 1.1 Poor seat condition. Example 1.

Plate 1.2 Poor seat conditions. Example 2.

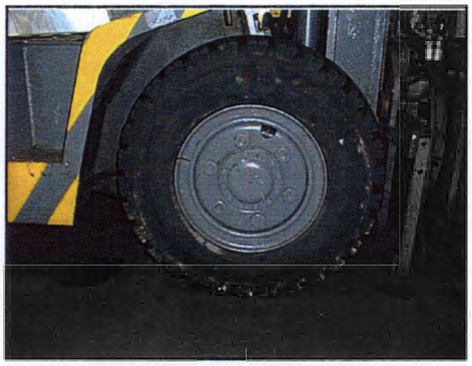


1.7.2.2 Tyres

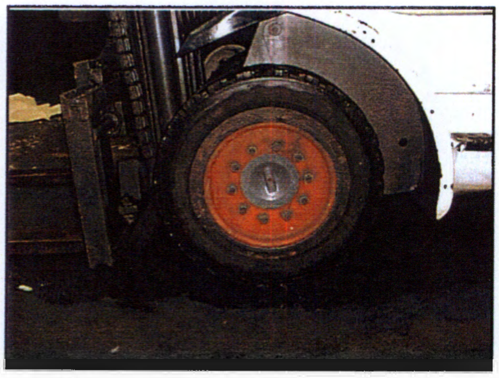
Forklifts are generally fitted with two types of tyres, solid cushion tyres, made from solid rubber with no inflatable inner, and pneumatic inflatable tyres that use air to maintain their shape and operational integrity. This factor could have an influence on vibration exposure characteristics, due to the fact that the vibrational energy travels up through the tyre structures before entering the vehicle body and chassis and eventually the driver. The tyre structure would thus have an effect either attenuating or amplifying the vibrational energy as it is transmitted up into the chassis.

In a study conducted by Malchaire, Piette and Mullier (1996), all the possible factors that may have an influence on the vibration production, transmission and exposure, were evaluated in a sample of five different models of forklifts, having four types of tyres, two types of seats, two types of driving tracks, and driven while loaded and unloaded. The results of the tyre test runs showed that on the chassis or floor of the forklifts the weighted vibration acceleration amplitudes did not differ between the tyre types significantly.

Plates 1.3 and 1.4 Two examples of pneumatic forklift tyres.



Plates 1.5 and 1.6 Two examples of solid rubber forklift tyres. Note the absence of shock absorbers in 1.5 (indicated by red arrow).



However when coupled with the different seat designs the tyres had an effect on the vibration damping abilities of the seat due to the slight frequency variations in the vibration exposure, and a complex inter-relationship between all the variables and factors was shown to exist. The worst combination seemed to be that of inflated tyres and a non-suspended seat, and the best was that of inflated tyres when a special low cut-off frequency seat was used. In the case of normal low cost seats usually found on forklifts they however recommend cushion tyres as the best combination.

1.7.2.3 Vehicle and Engine Produced Vibration

Vibration levels may also vary between various vehicles due to their individual design and construction, as well as the method of propulsion, which includes liquid petroleum gas (LPG), diesel, petrol internal combustion engines or even electrically powered. Malchaire, Piette and Mullier (1996), found in their study when testing three diesel and two electric forklifts, that the weighted acceleration amplitudes of the electric forklift were significantly lower ($0.2 m/s^{-2}$) perhaps due to the reduced speeds of operation, or the smoother operation of the electric motor as compared to the diesel internal combustion engines. However on the contrary the vibration amplitudes on the seat did not vary much for all 5 vehicles, and they concluded that the vehicle effects are small compared to other factors. Vehicle maintenance and tuning also play an important part with vibration levels expected to increase as the vehicle gets older with low maintenance and repair schedules.

1.7.3 Factors in the Driving Environment

1.7.3.1 Driving Speeds

Driving speeds will have an effect on the production and transmission of vibrational energy, as the more energy that is used or produced by the forklift to move at greater speeds the more vibrational energy will result. Anecdotal evidence is common regarding the speeds that forklift drivers are renowned to drive at, as often the job has to be finished very quickly and increased speeds are needed in order to comply with this requirement. Piece work will also aggravate this problem.

Malchaire, Piette and Mullier (1996), did not look specifically at different driving speeds, but did point out that various interactions exist between variables. In their study the greatest vibration accelerations were experienced by the lightest driver driving the fastest speed, and the lowest for the heaviest driver travelling at a slower speed. They also point out that when the forklifts were loaded drivers tended to drive slower, which reduced the vibration levels experienced. Burdorf and Swuste (1993) add to this by pointing out that driving surface and speeds normally operate in opposite directions, since rough terrain will restrict the speed and increased speeds would be expected on smoother surfaces.

1.7.3.2 Loads Carried

The loads carried by the forklift also have an effect on the vibration characteristics and amplitude. This is usually due to the reduction in speeds needed to carry the load safely. However Wilder, Pope, and Magnusson (1996), also add that industrial vehicles are designed to move heavy loads, and offer a design challenge requiring tyres, suspensions if possible, and chassis that can carry these loads. However, when empty the damping effect of that extra mass is eliminated and the vehicle and operator experience higher acceleration levels. Malchaire, Piette and Mullier (1996), also found that accelerations are significantly greater with the forklift unloaded, with both the weight of the driver and the speeds driven also having an effect. The vibration levels recorded in their study showed reduction on the floor or chassis of the vehicle as well as on the seat, in the vertical (Z- axis) direction. It must however be borne in mind that the operational conditions of forklift materials handling include driving at least 50% of the time without a load, as loads are fetched and dropped off and then another load picked up. The vibrational exposures will thus be alternated between periods of higher and slightly lower levels, throughout the work shift, obviously with influences from driving speeds, surfaces, and even the weight of the loads carried.

1.7.3.3 Driving Surfaces

Forklifts in the normal industrial operational environment usually have a relatively smooth surface on which to drive, as the factory floor is usually of smooth concrete construction, and outside areas are usually tarmacadam surfaces. However, forklifts may also operate on badly maintained, uneven and damaged surfaces with obstacles such as holes, rocks and drains. Macadam surfaces may also degenerate if not adequately maintained. Most forklifts are not designed for "off -road" conditions, especially those supplied with solid rubber cushion tyres to prevent punctures. Coupled with this is the fact that forklifts have no shock absorbers like conventional vehicles. The loads lifted and carried on the forks would not be possible to raise off the ground because the shock absorbers would merely compress under the weight and the loaded forks would remain on the ground. This fact in itself makes forklifts unique to most other vehicles, and is a significant factor when considering controls and how to supply shock absorption protection from vibration to the exposed driver, yet maintain the functionality of the vehicle.

Malchaire, Piette and Mullier (1996), found that the track or driving surface had clearly the greatest effect on vibration levels, since the differences recorded by them on rough and smooth surfaces reached up to 1 m/s^{-2} both on the floor and seat of the forklifts tested with an increase in acceleration levels of up to 70% between the two types of surfaces tested. On average the accelerations were reduced by about 0.10m/s^{-2} on the seat as compared to the floor on the smooth driving surface, and about 0.25m/s^{-2} on the rough surface. It therefore can be seen that driving surfaces significantly affect the vibration levels and frequencies and the exposure characteristics and needs to be taken into account when evaluating any situation and making recommendations.

From the foregoing it can be seen that many factors can and do have an effect on the vibration exposure characteristics experienced in the operational environment, and on the vehicle, with the most noticeable being the driving surface. More research is still needed in order to understand fully the aspects of importance and the influence they have in order to address the problem holistically and ensure that as many factors as possible are controlled and addressed to reduce the exposures by designing the best possible operational environment and vehicles. However we also need to consider risk factors related to the drivers themselves.

1.7.4 Driver Risk Factors

Driver and driving factors also play a major role in the exposure scenario with aspects such as the driving speeds, nature of the work, and loads being carried also affecting the vibration exposure characteristics whilst driving.

1.7.4.1 Sedentary Driving Occupations and Posture

The driving occupation is classified as a sedentary one (Brendstrup and Biering-Sorensen 1987), with usually little or no physical exercise in most cases, unless other tasks and jobs are carried out to improve muscle tone and circulation; this increases the effects of vibration on the spinal column and vertebral discs. The twisting of the torso and stooping that occurs during the manoeuvring of loads, and reversing operations coupled with the vibrational shocks on the spine, and the poor posture that result from bad seating also adds to the strain and spinal loading resulting in back and other problems.

Burdorf and Sorock (1997), in a review article point out that observed effects of whole-body vibration studies, ie: back pain and other musculo-skeletal disorders may be due to whole-body vibration or to prolonged constrained posture. Most vibration measurements taken on industrial vehicles show moderate to high vibration intensities close to 4-5Hz the natural resonance frequency of the spine. Mechanical vibration in this frequency range causes the largest displacement of spinal structures and requires considerable muscle tension to hold the upper body steady. Driving a vehicle is also characterised by constrained sedentary postures for long periods, and these postures increase the interdiscal pressure. However since vibration and prolonged sitting are concomitant exposures for all professional drivers, the contributions of these risk factors are difficult to untangle in epidemiological research.

Sedentary occupations, that require long periods of sitting such as driving can also lead to a slackening of the abdominal muscles and to curvature of the spine which in turn is bad for the organs of digestion and respiration according to Grandjean (1990).

1.7.4.2 Twisting, Stooping, Bending and Physical Lifting

Vehicle driving involves sitting for prolonged periods as well as non-neutral trunk movements and postures, such as bending forward, stooping and twisting of the spine to look backwards. Such stressful postures have been found to be associated with an excess risk of back pain, in machine operators, carpenters and even office workers. Some driving occupations such as truck and tractor driving can often involve weight lifting and carrying, and it has been suggested that lifting or rapid posture changes after driving can contribute to back injury. Riihimaki *et al* (1989) found in their study that back pain symptoms were more common amongst drivers than the carpenters to whom they were compared, because carpenters work is presumably physically heavier than that of the drivers when judged on the basis of energy consumption, and they concluded that physical exertion does not have a linear relationship to back pain, and many other factors are present that have an influence on the situation.

With LPG gas powered forklifts drivers may have to replace the LPG gas bottle when empty. Although this is an atypical handling task this requires a fairly heavy weight to be lifted, and may increase the risk of back injuries on the already stressed musculo-skeletal system of the back. This factor should be considered in any ergonomics programme designed for forklift drivers.

Wikstrom (1993), conducted a study that dealt with how the human body is loaded during different combinations of symmetrical / twisted sitting postures and whole-body vibration, and found that rotation of the head only, without vibration, corresponds approximately to the level of discomfort and the EMG activity for whole-body vibration exposure of 1.0 m/s^2 in a symmetrical sitting posture. The pain and discomfort level generally increased with the twist of the sitting posture and with the vibration level, showing that twisting and awkward movements should be avoided as much as possible whilst driving, and preferably avoided altogether. Unfortunately the design of a forklift usually leads to these type of postures due to the tendency for heavier, larger and more bulkier loads to be carried, thus forcing the drivers to reverse more often and maintain a twisted posture in order to see where they are driving.

1.7.4.3 Length of Work Shifts and Intensity of Vibration Exposure

The literature indicates that an important factor is the time between each episode of exposure, which includes two factors namely the exposure period and the recovery period. With adequate time to recover or adapt, and particularly when lower vibrational forces are involved, there may be less harm to the body from repeated exposures. With increased work shifts and overtime an increase in vibration exposure would be expected, and with this would come a corresponding reduction in recovery time resulting in a situation of increased wear and tear and reduced recovery and repair leading to more pain and musculo-skeletal damage. If work shifts (exposure periods) were reduced, the corresponding rest (recovery) period would increase and a reduction in musculo-skeletal injuries and damage would be expected.

Plate 1.7 Body posture of a driver forced to reverse due to tall loads being carried.

Plate 1.8 Twisting posture necessary to manoeuvre tall loads into position.

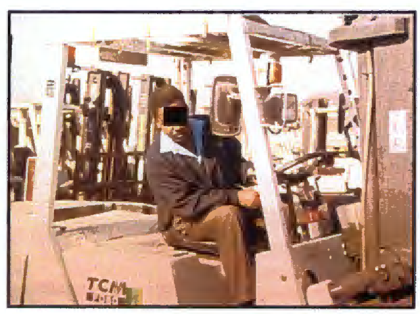


Plate 1.9 Stooping posture that places additional strain on the lower back of the driver.

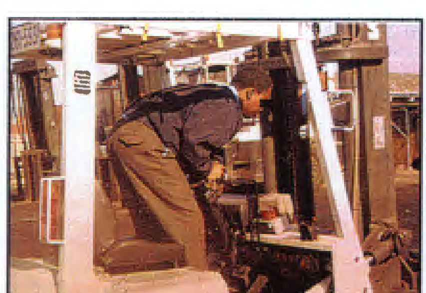


Plate 1.10 An overloaded forklift with a load obscuring the vision of the driver.

CHAPTER 2:
THE USE OF BACK BELTS

2.1 THE USE OF BACK BELTS

2.1.1 Introduction

Sometimes in industrial settings obscure and unproven devices and practices are used by workers as a protective device to prevent or reduce exposure or health effects associated with that exposure. Typically, no-one can give any scientific evidence that the device or practice actually works or information on where or why this belief in the device or practice actually started. A well known example in South Africa of one such belief is the quite widespread view that drinking milk every day will prevent an accumulation and associated adverse health effects of a variety of chemical substances ranging from paint spray solvents to lead and welding fumes. Even more disturbing is the belief that no other control measures are needed for protection such as local exhaust ventilation systems or respiratory protective equipment. Milk alone it is believed by some, will clear the body of chemicals and protect the exposed workers from the harmful effects of the chemical exposures.

Another common belief that on anecdotal evidence to be spreading widely in South Africa is the belief that back belts can offer protection for the musculo-skeletal system of professional drivers, against the effects of whole-body vibration exposure and reduce back pain and spinal degeneration. This section will attempt to review the current scientific evidence regarding the use of these belts for lifting activities and discuss some of the aspects related to their use in South Africa for other uses.

2.1.2 What is a back belt?

Potential for confusion regarding the naming and use of these belts in South Africa as opposed to the international situation could arise because of the differences in terminology and use. An attempt will be made to clarify definitions before investigating the topic area further.

Devices regarded by some as personal protective equipment are called back belts, lifting belts, abdominal belts or back support belts overseas when they are used for lifting activities in the workplace. A different type of lifting belt may be used for sports weight-lifting usually made of leather. They are however also known internationally and locally as kidney belts when used by sportsmen usually in off-road motorcycle riding such as motor-x or enduro racing or off-shore boat racing and snow mobile racing. This has sometimes led to confusion when the terms are used inter-changeably, even though the devices and their use differ from country to country and application. (See plates 2.1 and 2.2)

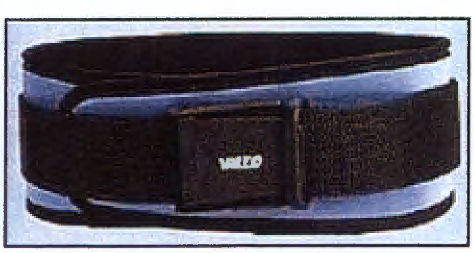
The devices themselves vary in design, but are generally manufactured from layers of elasticised material, with Velcro ends for attachment and adjustment, and may or may not have vertical support stays for additional support. The belts are usually thicker at the back and narrower at the front and are stretched around the persons lumbar region and waist area and fastened by Velcro at the front or side. This then is supposed to offer support to the lumbar area, by increasing the intra-abdominal pressure and supporting the spinal column, and surrounding organs.(See plates 2.3 to 2.6)

The kidney belts are used as a kidney support device in motor sport applications, such as off road motorcycle racing, that apparently help to hold the kidneys in place during rough terrain riding, and is supposed to prevent kidney bruising and blood in the urine, and are also non-specifically said to reduce pain. Although no scientific studies or literature in this regard could be found by the author, a commercial Internet web site of the Motorcycle Online Magazine (Canavan T. 1999. Available on-line at :URL:http://cgi.motorcycle.com/mo/mcdirt/stubbs.html.), made reference to these factors when carrying out a product review of a kidney belt. They are not evidently used for protection of the spinal column or to prevent musculo-skeletal disorders during these types of activities.

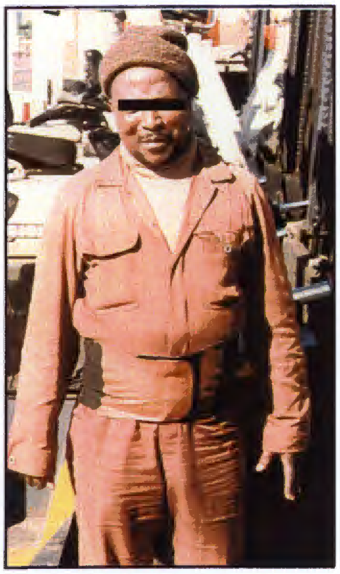
On another Internet site of the manufacturer of a specific kidney belt, Kevco/Stubbs Racing (Kevco/Stubbs.1999. Available on-line at URL:http://www.kevco-stubbs.com/press.html.). available on-line) reference is made to reports in the motor-cycle magazines as to the effectiveness of the kidney belts in reducing or eliminating low-back and kidney pain, supporting the kidneys, and internal organs. These are however personal opinions of commercial vendors of these belts and specialist off-road motorcycle magazines and offer no posting of scientific evidence to support these views or findings.

Plates 2.1 and 2.2 Kidney belts as used by moto-cross riders for back and kidney support.

Plates 2.3 and 2.4 Examples of back/kidney belts available for industrial use.



Plates 2.5 and 2.6 Two back/kidney belts in use in South Africa (Portnet study).



In South African industry today it appears to have become common practice amongst many forklift drivers to rely on back belts as a back support device to "prevent" back pain and injury. It is not known why or where the use of these belts by forklift drivers first originated in South Africa, but it is possible that they could have originally been used as a device that crossed over from their original use in motor-cycle off road sport.

The main guiding principles of occupational hygiene hazard control is one of engineering controls first and personal protective equipment as a last resort (Plog 1988). This is largely ignored in industry as is the case with other types of personal protective equipment from ear protection to respirators and other devices. The usual practice is for "cheap", quick fix solutions which are usually the major control measure considered first by employers, or requested by employees.

This review attempts to highlight some of the factors that need to be considered and understood regarding the use of back belts, in relation to whole-body vibration exposure, especially when driving forklifts. A review of some pertinent related literature is provided, as well as some areas of discussion and controversy in the local and international arena.

2.2 Review of Back Belt Studies

There are many studies on the effectiveness of back belt use for persons involved in manual lifting activities, but none of these in the literature reviewed by the author had investigated whole-body vibration exposure and back belt usage. In the absence of whole-body vibration studies or evidence regarding the use of back belts for vibration hazards, existing belt studies that looked at manual lifting will be reviewed. It is hoped that by showing the relevant findings and evidence of these existing studies the general picture, current knowledge and consensus of the international community can shed some light on the controversy regarding the use of these belts. This may have a direct bearing on the use the belts for other workplace activities, most notably as a protective device against whole-body vibration exposure. The studies reviewed include studies of the effectiveness of the belts when used in manual lifting field trials, biomechanical studies to investigate the mechanical effects of the devices on the human musculo-skeletal system, and physiological studies that investigated the physiological effects of the belts on other systems of the body, most notably the cardio-vascular system. A few studies looked at the psychophysical aspects of their use, with the studies based on the paradigm that allowed workers to select weights that they could lift repeatedly using their own subjective perceptions of physical exertion and on the change of perceptions when they used back belt supports.

2.2.1 Field Trials

Many studies have been carried out with regards to the effectiveness of back belts in reducing the incidence and severity of back pain and injury, as well as in reducing lost work time due to injury, and reducing medical and compensation costs. Many trials reported in the literature were fraught with methodological problems and suffered from the absence of control groups, no-post trial follow up, limited trial duration and insufficient sample size (Karwowski and Marras 1998). However the difficulty in executing a field trial must be acknowledged especially due to the many factors and variables that need to be controlled for. A selection of field trials as cited by Karwowski and Marras (1998) will be reviewed in this section, as summarised in table 2.1 .

A paper by Rys and Konz (1993), which reported on a number of studies (eight in all) that investigated the effects of back belts concluded that back belts have potential disadvantages as well as advantages, and may reduce lifting stress, but may also lead to a false sense of security while being worn and may weaken the body so that injury occurs when they are *not* worn.

Congleton *et al* (1993) also looked at eight studies related to the use of back belts, and in their conclusion they stated that they had initially hoped that back belts used during manual material handling tasks would be valuable in the prevention of back injury. However, the summary of this research indicates that lifting belts have not proven to be an effective piece of personal protective equipment and is not an effective means to increase lifting capacity in any controlled study. They go on to say that even if the lifting belts eventually prove to be effective, training and experience dictates that the most effective means of reducing or eliminating back injuries in order of precedence are engineering controls, administrative controls and then personal protective equipment. Lifting belts, regardless of style, is only personal protective equipment and should only be used as a last resort until engineering controls can be implemented. The best hope of eliminating or reducing back injuries is through ergonomic evaluation and implementation of engineering controls. The best opportunity to accomplish this is through education of management, design engineers, and the employee on ergonomics.

Table 2.1: Summary of field trials of the effectiveness of the use back belts during manual lifting activities.

Authors Name (Date)	Type of Study	Subjects (n)	Main Findings	Comments
Walsh and Swartz (1990)	Cohort Intervention 3 Groups -back belt and training; -training -control	81	No change in abdominal flexor strength and no reduction in accident rate or lost time noted.	Some benefits only seen in previously injured workers
Reddell (1992)	Cohort Intervention 4 Groups -back belt -back belt and training; -training -control	642	No significant difference between groups in incidence of back injury, lost time or workmens compensation	58% of belt wearers stopped using belts before end of 8 month field trial. Increase in number and severity of back injuries in belt groups after discontinuation of use
Mitchell *et al* (1994)	Retrospective Study	1316	Cost of back injuries higher with belt use as injury more severe than if belts were not worn	Study relied on self reported exposure and injury data
Kraus *et al* (1996) See text for more detail.	Cohort Intervention	36000	Reduction in compensation claims with ergonomic interventions and belt use	Caution advised in interpretation of results due to lack of robust effect and co-intervention (in addition to belts). Lack of scientific control over co-interventions. No comparable non-belt wearing group.
Thompson *et al* (1994) See text for more detail	Prospective 2 group pre-test post test	145	Frequency of back pain decreased	co-intervention study with back belts, back school programme and warm up exercises.
Van Poppell *et al* (1998) See text for more detail	Randomised control trial intervention 4 groups -training and back belt -training -back belt -control	312	Back belt use and training did not lead to reduction in incidence of back pain or sick leave	Compliance rates low with only 43% of subjects reporting belt use.

(Sources: Walsh and Swartz, 1990, Reddell, 1992, Mitchell *et al*, 1994, Kraus *et al*, 1996, Thompson *et al*, 1994 and Van Poppell, 1998 as cited in The Occupational Ergonomics Handbook, Karwowski and Marras, 1998.)

Another study by Thompson, Davidson and Hirsh (1994), investigated the attitudes related to back belt use amongst hospital workers, where a prospective study was used involving a two group pre-test post-test design, to investigate the influence of wearing back belts on employee job attitudes and the experience of back pain. Because the design also included a comprehensive back school preventive programme of education, and learned warm up exercises this study did not specifically only test the influence of the back belts and could not measure the exact effects of the independent variable because of co-intervention. They thus concluded that attitudes did improve with interventions, but this may have been the result of the widely known Hawthorne effect, where workers react in a certain way because they know they are being studied, and they react positively because of the feeling that management actually cares about them. Thompson, Davidson and Hirsh (1994), specifically allude to this in their article, when they say that workers reactions to the belts were generally positive, and several expressed a perception of managerial concern in provision of the belts. They go on to say that the frequency of back pain decreased with adjunctive interventions and/or back belts, but also point out that the back school training had failed to decrease injuries in the group. The decreased injury rate in the belt group actually occurred while the subjects were waiting to receive the belts (several months resulting from delays in procurement) and they conclude this reinforces the attitudinal dimensions of the belt effect.

Finally they state that there was some evidence of a placebo effect amongst the study groups in which perceived outcomes may have been self fulfilling. In the researchers opinion these conclusions could not be arrived at from the study design implemented and conducted in the Thompson, Davidson and Hirsh (1994) study and would need further investigation and study before they can be verified.

A study by Kraus *et al* (1996), frequently mentioned in the debate around back belts, included 36000 employees of Home Depot retail stores in the United States, in a well-designed cohort study to investigate the preventive value of lumbar back belts in healthy employees, ie: primary prevention. Belt effectiveness was assessed as the difference in the company's injury claim rate for back pain before and after use of belts. The results showed a 34% reduction in claims after use of belts. However, various criticisms of the study have arisen: Firstly the belts were introduced along with a "back belt policy", which may have included a training component and/or other factors possibly affecting rates. This was not clearly stated in the journal article and it is sometimes unclear if they are crediting the results to the policy or the belts themselves, or whether it is the overall strategy of training plus support, that works. The findings of the study may have been invalidated by co-intervention. Secondly, changes to the injury claim procedures policy took place in the state of California during the study, resulting in greater difficulty in getting low back pain claims accepted for compensation. The reduced claim rates may have been an artifact of changes in compensation procedures. However, a recent fact sheet on back belts by NIOSH (Available on-line), reference is made to this study, which credits the mandatory use of back belts in a chain of large retail hardware stores with substantially reducing the rate of low back injuries. Although the study provides limited evidence that back belts may be effective in some settings for preventing back injuries, NIOSH still believe that evidence for the use of back belts is inconclusive, and the question of the effectiveness of back belts remains open.

A recent study by Van Poppel *et al* (1998), from the Vrije Universiteit of Amsterdams Institute for Research in Extramural Medicine (EGO-Institute), assigned 312 airline freight handlers in a randomised controlled trial to four groups consisting of:

1. One group receiving education (lifting instructions) and lumbar support (back belts);
2. One group receiving only education;
3. One group receiving only lumbar support; and
4. One group receiving no intervention.

The researchers came to the conclusions that, lumbar supports or education did not lead to a reduction in low back pain incidence or sick leave and based on the results the use of education or lumbar supports cannot be recommended in the prevention of low back pain in industry.

2.2.2 Biomechanical Studies

Other studies investigated the effects of the belts on factors such as Intra Discal Pressure (IDP), Intra-abdominal Pressure (IAP), and Electromyographical (EMG) activity of the relevant back muscles, during various manual lifting and other activities. These were carried out in order to establish the biomechanical effects of the use of belts on the support structures of the lower back to investigate the claims made that back belts offer support of the musculoskeletal-skeletal structures through an increase in intra-abdominal pressure and an associated relief in the muscle activity thereby reducing the spinal loadings.

Table 2.2: Summary of studies on the biomechanical effects of back belts during manual lifting activities.

Authors Name (Date)	Type of Study	Subjects (n)	Main Findings	Comments
Nachemson *et al* (1986)	Experimental Intra-abdominal pressure (IAP) during Valsalva manoeuvres.	?	Increased IAP with belt use increased lower back compressive load	Incorrect to conclude therefore that an increase in IAP from belt use relieves compressive load on spine and offers protection.
Mcgill and Norman (1987)	Analytical model and data collection from subjects lifting loads with belts.	3	Build up of IAP required increased activation of abdominal muscles. Increase in low back compression and not reduction as was thought.	Belts increased loading on back and could increase damage and injury.
Mcgill *et al* (1990)	Experimental -wearing belt -without belt	6	Wearing belt increased IAP by 20% ave. No change in activation levels in low back extensors or abdominal muscles.	It is expected that if IAP increases then this helps support the lower back extensor muscles and this should reduce extensor muscle activity, but this assumption is incorrect.
Lander *et al* (1992) Harman *et al* (1989)	Laboratory experiments with repeated weight lifting	?	Increased IAP with back belt use.	Contentious issue whether IAP is a good indicator of spinal force.
Mcgill *et al* (1994)	Experimental trial Tested flexibility and stiffness of lumbar torso with back belt.	35	Stiffness of torso increased about the lateral bend and axial twist axes when subjects rotated to full flexion.	It appears that belts assist to restrict range of motion about lateral bend and axial twist axes, but do not help when torso is forced in flexion as in manual lifting activities.
Reyna *et al* (1995)	Experimental -wearing belts for testing of low back extensor muscle activity.	22	Belts found to provide no enhancement of function.	Very short 4 day trial period.
Ciriello and Snook (1995)	Experimental trial lifting with and without belt. Tested median frequency of low back EMG which is sensitive to local muscle fatigue.	13	No modification seen to EMG by presence or absence of belts.	Indicates that belts do not significantly alleviate the loading of back extensor muscles and muscle fatigue.

(Sources: Nachemson *et al*, 1986, Mcgill and Norman, 1987, Mcgill *et al*, 1990, Lander *et al*, 1992, Harman *et al*, 1989, Mcgill *et al*, 1994, Reyna *et al*, 1995, Ciriello and Snook, 1995, as cited in the Occupational Ergonomics Handbook, Karwowski and Marras 1998)

A recent study conducted by Kumar (1997), came to the conclusion that the intra-abdominal pressure does not follow the spinal loading pattern or electromyographical patterns of the spinal muscles. It was found to be neither complimentary nor contradictory to these variables. Based on these observations, it was concluded that the intra-abdominal pressure is not an active spine load-relieving mechanism. Yet this is one of the key elements of the claims by proponents of the use of these belts in their explanation of how they work to support the back and prevent injury! Thus, there is little evidence from past biomechanical studies to support the claims made by the belts proponents, that the use of back belts results in beneficial biomechanical effects. If back belts do supply symptomatic effects the mechanism is not biomechanical.

2.2.3 Physiological Studies

Studies have also been carried out with regards to the physiological effects of these devices on the cardio-vascular system of individuals exercising whilst wearing a back belt. These studies have been prompted by concerns about increased stress placed on the cardio-vascular system leading to an increased risk of heart problems and perhaps even cardiac arrest, especially in more susceptible workers such as the older worker.

Hunter *et al* (1989), showed in their studies during lifting exercises that blood pressure was significantly higher (up to 15mmHg), and heart rates also increased when belts were worn. The Velcro fastening type elastic belts were also shown to significantly increase diastolic blood pressure even for quiet sitting and standing both with and without hand held weights, during a trunk rotation task and during a squat lifting task.

It could therefore be hypothesised that since one of the physiological effects of whole body vibration on the human body is to increase blood pressure at low frequencies of around 5 Hz (Schoeman and Shroder 1994:246) even more stress could be placed on the cardiovascular system if using a belt thus posing a greater risk to drivers with compromised cardio-vascular systems and high blood pressure.

Another criticism of the wearing of back belts is that injuries could result due to the fact that wearers may develop a false sense of security regarding their ability to lift heavier weights and also an increased risk of injury when they are not wearing the belts. This psychophysical factor was tested in an experiment by McCoy *et al*, 1988.

Table 2.3: Summary of studies on the physiological and psychophysical effects of back belts during manual lifting and other mechanical activities .

Authors Name (Date)	Type of Study	Subjects (n)	Main Findings	Comments
Physiological Effects				
Hunter *et al* (1989)	Trial with subjects performing dead lifts, bicycle riding and bench press with and without belt.	6	Blood pressure and heart rate higher when a belt was worn.	It was concluded that individuals with compromised cardio-vascular systems are at greater risk when exercising with belts.
Rafacz and Mcgill (1996) See text below	Experimental with subjects performing sedentary and mild activities with and without belts.	20	Significantly increased diastolic blood pressure.	Significant evidence that belts increase blood pressure and may increase load on cardio-vascular system.
Psychophysical Effects				
McCoy *et al* (1988)	Experiment with subjects repeatedly lifting loads from floor to knuckle height with and without different belts.	12	Wearing belts increased the loads that subjects were willing to lift by 19%.	Some concern has been shown that wearing belts fosters an increased sense of security and may lead to increased risk of back injury when no longer worn, or overloading of back.

(Source: Hunter *et al*, 1989 and Rafacz and Mcgill, 1996 and McCoy *et al*, 1988 as cited in the Occupational Ergonomics Handbook, Karwowski and Marras, 1998.

2.2.4 Compliance with the Use of Back Belts

The use of personal protective equipment has for many years been a problem area in the practice of occupational health and safety, as these kind of devices are often provided to employees with no training in their proper use, limitations, storage or even maintenance and care. Employers are seen to be doing something to protect their employees, yet the exposures remain a problem.

The problem often lies with improper use by wearers, modifications that make them less effective or completely ineffective and non-compliance with their use. Non-compliance occurs for many reasons including, discomfort, interference with communication, work movements and tactile sensations and even due to a "macho" type reaction which sees their use as a threat to image or masculinity. It has been shown that many types of personal protective equipment, from respirators and hearing protection, to helmets goggles and gloves, do in fact have their place in industrial settings and if used correctly and are if, of a suitable approved make, can protect against various occupational hazards.

In various back belt studies compliance with use has been looked at in order to ascertain their acceptability, use and comfort factors in relation to the worker and his/her work environment.

Van Poppel *et al* (1998), measuring compliance every month with a questionnaire found lower levels of compliance with only 43% of the study group actually reporting the wearing of the belts in half of the questionnaires. In random checks by the investigator at the workplace, compliance was approximately the same as was reported in the questionnaires, ie: 40-50%. When subjects were asked how satisfied they were with the back belts, 49% reported the belts restricted their freedom of movement, 48% reported they could not sit comfortably with the support, and 45% thought the support was too warm.

Congleton *et al* (1993), also reported on compliance of use of back belts, where they noted that 58% of participants discontinued belt use before 8 months, and for whatever reason these participants subsequently had a marginally higher incidence of injury, and thus raised the belt safety question in a different context.

2.2.5 Conclusion

The debate around the benefits of the use of back support belts has raged on and on as people from both sides argue for and against their use. However all scientific evidence that exists in the literature concerning the use of these belts applies only to lifting activities.

With the lack of scientific evidence regarding the use of these belts for protection against whole-body vibration we can only look to the studies that have been carried out for activities where these belts are used, ie: manual lifting, where the evidence for their effectiveness remains very weak. For protection against whole-body vibration there is no scientific basis for their use, nor any biological or physiologically plausible mechanism to support a hypothesised protective effect against whole-body vibration. In addition to this compliance studies have shown that many workers tend not to use them, as occurs with most types of personal protective equipment thereby casting a further shadow on their effectiveness.

What is preferable is that a full ergonomic risk assessment of the work situation is required firstly, and the identified risks must then be addressed and eliminated or reduced using sound ergonomic and occupational hygiene principles, and not a "quick fix" panacea to pacify workers. This is borne out in the next section which reports on responses from the occupational health community to the use of back belts for whole-body vibration exposures.

2.3 The Global Perspective

The use of back belts is controversial and various studies discussed have looked at different makes and types of back belts without coming up with any satisfactory scientific conclusions as to their effectiveness in protecting the lower back.

On the international scene, it has been found that in many countries , including Canada, USA, Australia and most European countries, back belts are not used as a major protective device during lifting, as ergonomic principles are highly regarded and applied in developed countries.

An e-mail based survey (HS-Canada 1997 Available at http://www.hronline.com/forums/ohs/9803/0051.html), was conducted by the author on three major health and safety mailing lists, including the Health and Safety Canada list (hs-canada@kate.ccohs.ca) with +-381 list members, the Safety List (safety@list.uvm.edu) with +-2500 members, and the Global Occupational Hygiene list (globalocchyg-l@cornell.edu) with +-600 members. A questionnaire was posted referring to the use of back belts and especially with reference to their use as a protective device against whole-body vibration exposure and effects. The response was fairly low (21 respondents), but the majority (18 respondents; 86 %) responded that they had never heard of the use of these belts as a protection against whole-body vibration. The other three respondents said the did not know if back belts were used in their countries for driving or they combined the use of back belts for lifting tasks and driving activities.

Some (12 respondents; 57 %) said they were used for lifting jobs only, and most (15 respondents; 71 %) pointed to other alternative control measures that were more effective and better to use in the work environment.

2.3.1 The Health and Safety Community

Upon questioning either personally or via e-mail, various experts around the world involved in either the field of occupational health and safety, ergonomics or whole-body vibration research, the general consensus of opinion regarding the use of these belts was that they remain an unproven protective device and other more proven methods of control and protection should be used. Not one of the people consulted by the author had heard of the use of these devices as a protection against vibration exposure. A selection of the responses to questions from the author are provided below from various international researchers, as well as representatives from the World Health Organisation and the International Labour Organisation.

Dr Alex Burdorf from Erasmus University in the Netherlands, a renowned researcher in whole-body vibration said (e-mail communication Burdorf 1998) "that in Holland back belts are hardly used for lifting activities and certainly not for whole-body vibration" and in a later e-mail communication (Burdorf 1999) he pointed out "that there is no scientific evidence available related to back belts as a protective device for whole-body vibration induced back pain".

Stuart McGill, a professor of Spine Biomechanics at the University of Waterloo, Canada, echoed these sentiments when he said (e-mail communication McGill 1999), that "back belts really would not help against whole-body vibration, and ergonomic interventions is where the savings are".

Mcgill (1999), recently published another article regarding this issue and pointed out that these devices continue to be sold and marketed to industry in the absence of a regulatory requirement to conduct controlled clinical trials similar to that required of drugs and other medical devices. His main conclusion is that given the available literature, it would appear the universal prescription of belts is not in the best interest of globally reducing both the risk of injury and compensation costs. Uninjured workers do not appear to enjoy any additional benefit from belt wearing and in fact may be exposing themselves to a risk of a more severe injury if they were to become injured and may have to confront the problem of weaning themselves from the belt.

A representative from the Occupational Safety and Health Branch of the International Labour Organisation (ILO) Mr Pavan Baichoo, also points out (e-mail communication Baichoo 1999) that "the ILO has very little information on the use of back belts and nothing regarding their use for protection against whole-body vibration, and basically support the general consensus of the scientific community that the most effective means of minimising the likelihood of back injury is the development and implementation of a comprehensive ergonomics programme".

Mrs Berenice Goelzer from the World Health Organisation (WHO), Occupational Health and Safety section also indicated (e-mail communication Goelzer 1999) that "the WHO does not have any information on the use of these devices".

2.3.2 International Occupational Health and Safety Agencies and Organisations

The use of these belts for manual lifting as a protective device is generally discouraged and warned against by many international occupational health and safety organisations and agencies, such as the, and the American Industrial Hygiene Association (AIHA). The AIHA in its position paper on ergonomics (AIHA 1999. Available on-line from URL:http://www.aiha.org/papers/ergo/html.), states that at this time the AIHA does not have an opinion on the effectiveness of back support belts for the prevention of musculo-skeletal disorders. They go on to say that the potential benefits of back supports/belts and wrist splints/braces used in the context of medical treatment of specific conditions is generally recognised. However the scientific studies related to the use of these devices as personal protective equipment for manual lifting and other activities are controversial, conflicting and ongoing. Various studies over time have indicate that, when these devices are used as personal protective equipment, potential benefits may be balanced or even outweighed by potential adverse health effects. Additional research is needed to make recommendations for future use in the workplace, and at this time there is no reliable basis for affirming or refuting the hypothesis that back/support belts function effectively as personal protective equipment. AIHA does not currently advocate their use for the prevention of musculo-skeletal disorders, and the preferred method of control is the proper design of jobs, equipment, products, workplaces and practices.

In 1994 the director of NIOSH in the United States formed a working group of Health and Safety Professionals to review the literature related to Back Belts (NIOSH 1994) The groups objective was to evaluate the information supporting the use of back belts to reduce manual lifting work related back injuries. The NIOSH Working Group found:

- That the effectiveness of using back belts to lessen the risk of back injury among uninjured workers remains unproven.

- There is insufficient information indicating that typical industrial back belts significantly reduces the strain on the back.

- There is insufficient evidence to show that the wearing of back belts reduces the risk of injury to the back.

- The use of back belts may produce temporary strain on the cardio-vascular system (circulation).

"Existing data suggests significant increases in heart rates and blood pressure, and the working group concluded that the use of back belts can put a strain on the cardiovascular system, and that individuals with high blood pressure may be at greater risk when exercising or working with back support"(NIOSH 1994).

In addition, mechanical studies have suggested the long-term use of back supports may decrease abdominal muscle tone and increase the likelihood of back injuries if the user discontinues with the use of the back belt (NIOSH 1994). This view is also held by the Worker s Compensation Board of British Columbia, Canada, where they point out in their ergonomics commentary web page (WCB 1995. Available on-line from URL: http://www.wcb.bc.ca/resmat/pubs/ergcomm/ergcomm1.htm.) that "long term use of belts may cause a loss of strength in the stomach muscles, which may then increase the risk of injury when a belt isn't worn".

In conclusion the Working group did not recommend the use of back belts to prevent injuries , and did not consider back belts to be personal protective equipment, but rather recommended the development of and implementation of a comprehensive ergonomics programme.

A Canadian Centre for Occupational Health and Safety alert titled: Weightlifting or Lumbar Support Belts in Manual Material Handling Work, (CCOHS 1997. Available on-line at URL:

http://www.ccohs.ca/ccohs/alerts/alert90.txt.), states, "these belts should not be used generally as a means of preventing back injuries. The weight of evidence on back belts suggests that they do not offer benefits in reducing occupational injury rates or absenteeism".

Similarly, the Workers Compensation Board of British Columbia, Canada, (WCB 1995. Available on-line from URL: http://www.wcb.bc.ca/resmat/pubs/ergcomm/ergcomm1.htm), re-affirm this view, by saying that they do not consider back belts to be personal protective equipment and studies have not shown that wearing back belts prevents back injuries. They point out that, in fact there is some evidence that wearing back belts may increase the risk of injury.

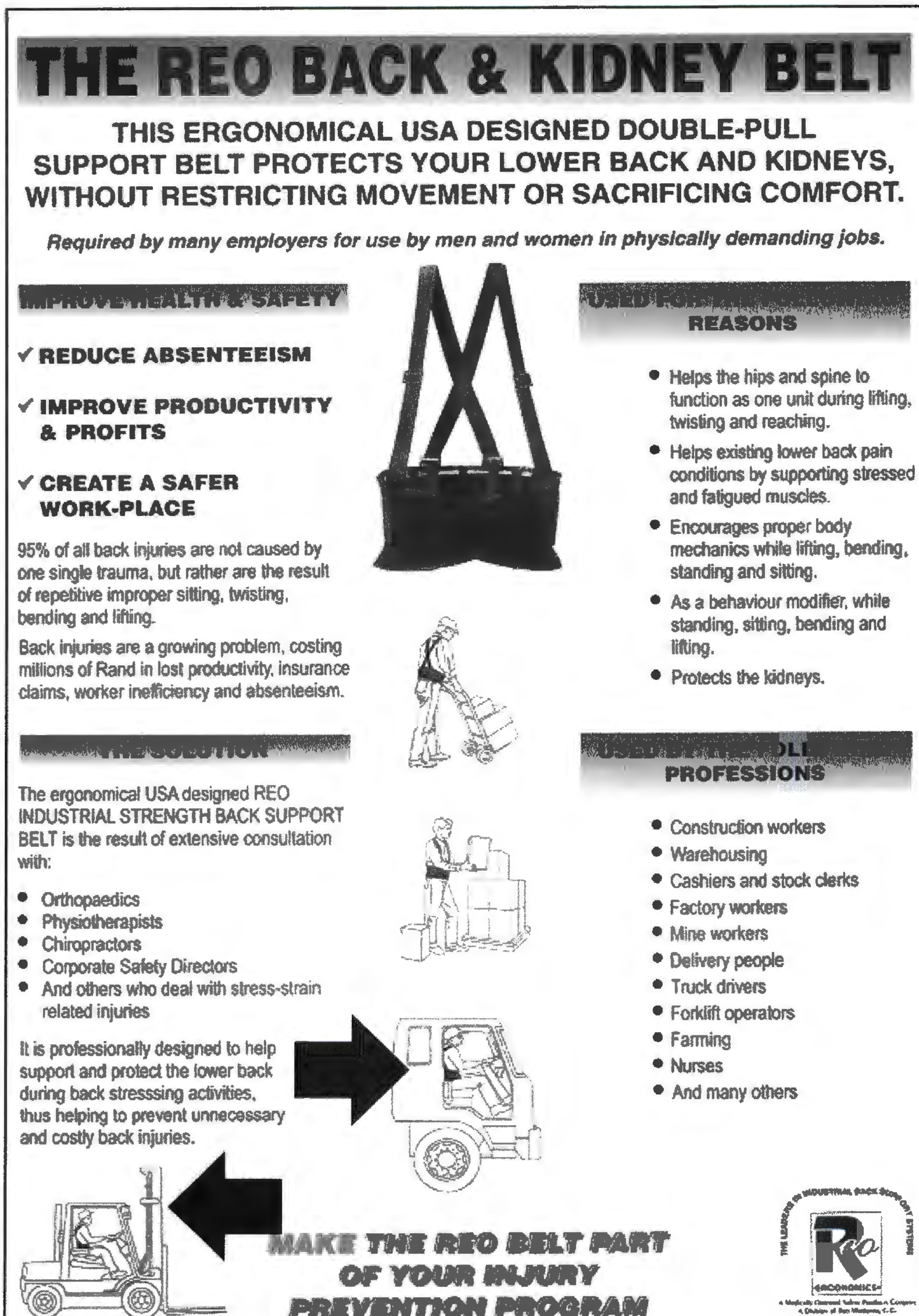
Liberty Mutual one of the largest workplace insurers in the world, points out, that lower back pain accounts for 18% of all workers compensation claims they handle and account for 30% of the costs, they therefore have a vested interest in any controls offered to reduce these figures.(Liberty Mutual 1999. Available on-line at URL:http://www.libertymutual.com/research/news/releases/press_x.html.) However, the researchers in the Biomechanics laboratory at the Liberty Mutual Research Centre for Safety and Health have investigated how these belts impact the strength of the back muscles, worker fatigue and body motion patterns. Tom Leamon, the vice-president and director of the research centre points out that the insurer's position is that there is insufficient evidence today to conclude that back belts help to prevent injuries. They are in the future planning to investigate the beneficial placebo effect of these belts, but in the absence of definitive data, Leamon recommends that companies approach back belts with caution. He says that a back belt can be a dangerous piece of personal protective equipment if it is thought to solve all problems and encourages workers to lift more weight. A back belt is no substitute for good ergonomic job design, nor is it a substitute for mechanical handling devices that help reduce the stresses of lifting tasks.

The overwhelming consensus from the international scientific community therefore, doubts the effectiveness of these devices as a protective device against lower back injuries. Moreover it should be pointed out that not one agency or governmental organisation even makes mention of the use of belts as a protective device against whole-body vibration exposure. Thus expert opinion offers no justification for their use in relation to whole-body vibration exposure. It must also be stated that the author could not find one research study that looked at the effectiveness of the back belts on protection against whole body vibration exposure or reduction of back pain or other musculo-skeletal injuries of drivers.

2.3.3 The South African Scenario

These belts are also used locally for manual lifting activities and the people with the loudest voices are often the vendors of these devices offering a panacea for a complex, widespread and often misunderstood problem. It has also become a phenomenon in South Africa to actually advertise back belts in industrial journals as a protective device for lifting and driving activities. With adverts in local health and safety journals often having a picture of a truck or forklift driver alongside pictures of lifting activities (Anon 1997). This also increases and encourages the use of these belts by drivers.

Figure 2.1 Back/kidney belt advertisement linking back/kidney belt use to vehicle driving (indicated by black arrows bottom centre and left) .



Ergonomics consultant Dr. Johan Hendrikse points out in an article by Brown, 1996 that:

- Mobility limitations imposed by these belts may reduce the suppleness and elasticity of muscles and tendons, potentially contributing to back pain.
- Belt support is inferior to a good exercise regimen that strengthens muscles and increases flexibility.
- Belts will not protect the spinal column from intervertebral disc compression caused by low frequency shocks experienced by vehicle operators eg: Forklift Drivers.
- Belts may provide a false sense of security, thus increasing the risk of injury.

The South African Society of Occupational Medicine (SASOM) does not advocate the use of back belts in keeping with international practice (e-mail communication H.Van der Merwe 1997) This however does not prevent their use in South African industrial settings for both manual lifting activities and to prevent lower back pain amongst professional drivers especially forklift drivers.

No local studies examining the use of back belts have been conducted in South Africa and all local references made in journals concerning the use of these belts is either in vendors advertisements or product reviews by the vendors themselves where selective reference is made to studies conducted overseas that still remain clouded in uncertainty and controversy.
Section 10 of the Occupational Health and Safety Act (85 of 1993), offers legislative control over designers, importers, sellers or suppliers of any article or substance used at work, which would include back belts. This is covered in the general duties imposed, where as far as is reasonably practicable, the supplier, manufacturer, importer, or seller has to ensure that the article is safe and without risks to health when properly used. This is unfortunately not applied to a large extent by the statutory body responsible, the Department of Labour, but could be used to force the suppliers of these devices to prove any claims made, and prove that no ill effects to workers health results from their use.

In conclusion what information we have suggests that outside South Africa, belts are not used for protection against whole-body vibration exposures, and amongst the professional health and safety community the general feeling is that other alternatives were recommended.

2.4 THE CONTROL OF WHOLE-BODY VIBRATION

2.4.1 The Hierarchy of Industrial Hazard Control Measures

Standard occupational health and safety practice recognises a system of control of industrial hazards that firstly encourages the implementation of the most effective controls, that do not depend on human behaviour and compliance, and then it follows a hierarchy downwards to the least effective controls, such as personal protective equipment which rely on the behaviour of humans.

Control methods for health hazards in the work environment are divided into three basic categories according to Plog (1996), namely;

1. Engineering Controls that engineer out the hazard either by initial design specifications or by applying methods of substitution, isolation, enclosure or other engineering technologies. In the hierarchy of controls engineering methods should always be considered first. Such built in protection, inherent in the design of a process or vehicle, is preferable to a method that depends on continual human implementation or intervention.

2. Administrative Controls that reduce employee exposures by scheduling reduced work times, rotation of workers from areas or tasks of high exposure to low exposure. Also included here is employee training that includes hazard recognition and specific work practices that reduce exposure eg: correct seat adjustment for weight to maximise vibration damping.

3. Personal Protective Equipment for employees to wear to protect them from their environment. This includes anything from respirators, and gloves to full body suits, but must have proven capabilities of protection for the worker, as the device stands as a barrier between the worker and the hazard, and if the barrier fails, immediate exposure is the result. This is considered a secondary control method to engineering and administrative control and should be used as a last resort. However these should only be used if proven protection is offered by the device . This is not the case with the use of back belts, which remain an unproven device that may give a false sense of security for exposed workers.

Table 2.4: The hierarchy of control measures for whole-body vibration.

ENGINEERING CONTROL MEASURES.	ADMINISTRATIVE CONTROL MEASURES.	PERSONAL PROTECTIVE EQUIPMENT.
Workstation Integration and Vehicle Ergonomics/Use of Rear View Mirrors	Reduction/Limiting of Driving Speeds	No Proven Personal Protective Devices available.
Ergonomically Designed Seats	Rotation of Workers	
Vibration Isolation/Attenuation	Pre-work Exercise/Stretching Programmes / Reduction of Twisted and Awkward Postures	
Smooth Driving Surfaces / Use of Uni-Directional Tracks	Medical Monitoring and Pre-employment Medicals	
Use of Correct Tyres	Health and Safety Policies and Programmes	
Vehicle and Seat Maintenance Programme	Training and Education of Drivers	

In relation to back injuries the NIOSH fact sheet, (Available on-line at URL:http://www.cdc.gov/NIOSH/backfs.html) suggests that rather than relying solely on back belts, it recommends that employers and workers minimise their risk of back injury by developing and implementing a comprehensive ergonomics programme focussing on prevention and :

1. Include an assessment of all work activities to ensure that tasks can be accomplished without exceeding the physical capabilities of the worker;

2. Incorporate comprehensive ongoing training for all workers;

3. Provide a surveillance programme to identify potential work-related musculo-skeletal problems and;

4. Include a medical management programme.

When selecting a seat and its suspension system-fixed mechanical or air-suspended, it is important to consider the type and design of the vehicle, as well as the conditions, such as climate, terrain and altitude in which the vehicle will be operated.

A vehicle maintenance programme should include an organised and efficient section for seat maintenance. Certain forklift manufacturers have gas filled shock absorber type suspended seats that according to the maintenance specification need to be checked and replaced annually in order to ensure continuing effectiveness in protective damping, however this is seldom carried out in practice, as maintenance is usually done with the aim of keeping the vehicle operational and on the road. Without proper seat maintenance the ergonomics and vibration-attenuation qualities of the seat may be detrimentally affected.

In South Africa there is no readily available reference source for seating design dimensions like an South African Bureau of Standards (SABS) code of practice or specification. There is a South African military document published in 1998, that covers the Specifications for Seats for Military Land Vehicles and makes provisions for their requirements and quality assurance (SANDF 1998). However this is a restricted document and is not freely available.

Some research and seating guidelines that is available on various seats and in various applications, was carried out by the Pittsburgh research laboratory, that developed Human Factors Design Recommendations for Underground and Mobile Mining Equipment, (Pittsburgh Research Laboratory 1997. Available on-line at URL:http://www.cdc.gov/niosh/pit/hfg_seat1.html.), that could be adapted and give a good indication of the aspects to be considered when designing a vehicle workstation within certain limits and for specific operational conditions.

The seating design guidelines include four areas that need attention:

Seat Dimensions - Design the seat to fit and adjust to body dimensions, and distribute weight to relieve pressure points and support posture. In other words, the seat should be comfortable.

Vibration Isolation - Provide design features to guard against the dynamic forces caused by

Although these prevention methods refer to manual lifting, they may well be applicable to whole-body vibration exposure work situations such as driving.

2.4.2 Engineering Controls

2.4.2.1 Introduction

Engineering control should address factors such as driving terrain and surfaces, forklift designs, ergonomically-designed seats to dampen vibration, (preferably systems independent of the driver and offering adequate lumbar support). Many problems are experienced with the engineering design of forklift seating and vibration damping systems, as shown in the studies mentioned earlier.

2.4.2.2 Seat Designs

With suspended seats three main problems are experienced. Firstly the operator must adjust the seat to his body weight. This requires training and motivation, and many workers do not understand the need to do so. Secondly the seats must be serviced and maintained according to manufacturers specifications. Thirdly the seats usually have limited isolation and damping at low frequencies.

What constitutes a good seat? Hendrikse (1996), points out that a good seat should be able to attenuate vibrational frequencies of between 0.5 and 80 Hz. However from the evidence provided by Burdorf and Swuste (1993) the effectiveness of seat attenuation cannot be assumed, and in fact the seat may actually increase or amplify the vibration exposure of the driver. Another criteria cited by Hendrikse (1996) is that the seat should be able to accommodate at least the 5th to 95th percentile user population and provide a comfortable seating position with adequate adjustment controls, easily accessible to the user with the seat adjusted to any position. Furthermore the seat should be compatible with the vehicle in which it is installed in the sense that the driver should be able to reach and fully actuate or manipulate all the primary controls while being restrained by a suitable seat belt if necessary. The seat base should provide proper support and not be contoured to the degree that movement is restricted or that sufficient pressure is exerted to reduce blood circulation to the lower leg. The backrest should provide vertical and lateral support, particularly to the lumbar region of the spine.

rough roadways and minor collisions that tend to "unseat" a person.

Workstation Integration - Design the seat so that it does not hinder the operator's ability to control the machine or hinder ingress or egress from the workstation.

Maintainability - Design the seat so that maintenance personnel can easily maintain or replace it.

The research group point out that seating for most industrial applications generally includes an adjustable backrest, a suspension system, a fore-and-aft track adjustment, an up-and-down seat adjustment, and sometimes an armrest and/or footrest. Some manufacturers also include devices for lumbar region support.

They state that the designer should attempt to design seating, bearing in mind that the operator's comfort and productivity depends in large part on his/her seating. This factor is often ignored by the buyers of such equipment, where speed, power output, maintenance and operational costs are the first considerations and often the ones on which the purchase decision is based, with no consultation with the drivers or health and safety personnel, resulting in a “cheap”, highly productive machine, that is hopelessly inadequate for the health and safety requirements of the driver.

A properly designed seat would provide adequate support, would not impose any undue stress on the body, and would allow optimum posture. It would be comfortable, not contribute to fatigue, and allow the worker to be productive. It would address such factors as the alignment of the spine to reduce intra discal pressure, how much work the muscles have to do to maintain required work postures, and the compression of the blood vessels and nerves at the back of the thigh and behind the knee. Due to the differences in size and shape of workers, adjustability would be incorporated into the seat, i.e. operators could move it up and down and forwards and backwards.

Padding would prevent discomfort and decrease the effects of whole-body vibration and shock. Its design would reduce interference to trunk, head, and limb movement and visibility. An adjustable backrest and armrests would give additional postural support and be an aid to standing up and sitting down. (For more detail on seat design guidelines refer to appendix K)

Section 10 of the Occupational Health and Safety Act (85 of 1993), implies a responsibility on the part of manufacturers to ensure the design of forklift seats and other components ensures the safety and comfort of the driver. However, many seats currently available do not reduce the vibration exposure to below recommended limits. Despite this fact, there is little enforcement by the Department of Labour due to a lack of expertise in vibration issues and a lack of monitoring equipment, funding and manpower.

Other technological developments for vibration control include vibration isolation of driving cabs, reduction of driving speeds using speed governors, hydrostatic drives, tyre selection and raised cabin heights. However these technologies are not as widely used as they should be. Purchasers and users of these vehicles do not include them in the buying specifications and do not insisting on increased vibration control. Secondly new innovations and controls are seen as optional extras that incur increased expenditure. Price, performance, maintenance costs and fuel efficiency are often the main governing factors in vehicle selection often at the expense of ergonomic and vibration control technologies.

2.4.2.3 Vibration Isolation of Driving Cab

Certain forklift manufacturers have developed a system whereby the driver is not only isolated from vibrational energy by the seat, but the actual driving cab is also isolated by being suspended and supported by gel-filled rubberised shock absorption cushions that reduce vibration levels before they reach the seat where attenuation then takes place. The driver's cab is thus insulated from the vehicle itself. This type of double isolation and damping appears to go a long way to reducing the vibration exposure of the operator but remains confined to a few manufacturers and is not widely used as a standard control technology.

2.4.2.4 Reduction and Limiting of Driving Speed

This technology has been around for a long time and is widely used in many other types of vehicles, where the speed is governed by a device that does not allow engine speeds above a certain revolution per minute, thereby ensuring slower operational speeds and reduced vibration production and transmission. Secondly engines have been developed that operate normally at lower speeds or revolutions per minute, not as a control against excessive speeding, but because lower engine speeds mean less noise and vibration, reduced exhaust gas emissions and lower fuel consumption. This has been achieved by using hydrostatic pump systems to achieve maximum power for lifting materials and cargo, at much lower engine speeds, thereby also lowering the engine produced vibration and ultimately the driver exposure.

2.4.2.5 Reduction of Vehicle Vibration

In addition to the engine produced vibration as discussed above, another source of vibration in any vehicle is the gearbox system and transmission. Some forklifts have been designed with an innovative hydrostatic drive that ensures continuous, smooth, lower vibration and force-coupled power transmission. This does away with the need for gears, differentials and the normal clutch driven system of engine power transmission, thereby reducing the vibration levels further.

2.4.2.6 Off-Road Tyres

These tyres are available for forklifts, but very rarely used in South Africa, presumably due to prohibitive costs and lack of availability. The tyres are suited and manufactured for rough terrain driving, and are similar in design to off road tyres for 4 X 4 off road vehicles, being wider than the normal road tyres and having much bigger and higher tyre treads for maximum traction. This improves the capability of the vehicle to traverse cross-country over uneven rough terrain and thereby also allowing for less vibration transmission from the surface up into the chassis of the vehicle and eventually into the driver.

2.4.2.7 Increased Driving Cabin Heights

Some manufacturers offer forklifts that have a design that increases the height of the driving cabin, and these are used especially in industries where loads carried are normally of excessive heights, for example the canning and bottling industries where stacked pallets are used for ease of movement and storage of containers. The increased height of the drivers cab allows better vision over and above the tall load and reduces the need to reverse to the load off point, thereby reducing the need to twist the body into an awkward position in order to see the road ahead as the driver reverses. This in turn reduces the risk of additional back strain and injury, and of course will reduce the additional effects of vibration loading on the twisted spine of the driver.

2.4.2.8 New Innovations in Vibration Control Technology and Research

Some research carried out by Stein (1997) looked at the designing of a seat with an active electro-pneumatic suspension system, that would actively reduce vibration energy before it is transmitted to the driver. This was an alternative to the use of passive pneumatic or spring suspension system so common today, that operate in static or quasi-static conditions Ie: the system variables change slowly thereby not offering enough vibration attenuation to reduce the energy sufficiently. Stein (1997) concluded with his new system, that the vibrational energy could be reduced on average between 30-40% as compared to the passive systems in use today, and he goes on to say that this amount of attenuation would enable machine operators to operate for a full work shift without risk to their health. This assumes that health based vibration limits are correct and a dose-response relationship exists. However as previously discussed the nature of the exposure-effect relationship is complex and subject to many effect modifiers. However when we look to vibration reduction on its own any new developments that reduce exposure further than existing controls should be taken note of and developed further.

Two other researchers, Wan and Schimmels (1997), did some modelling to investigate the optimal seat suspension design based on minimum "simulated subjected response", in order to find the seat suspension parameters ie: mass, spring and damping properties, that would yield optimal vibration isolation, to minimise vibration transmission to the vehicle operator. Their results after some complex calculations and testing showed that the optimal seat damping in their tests was sufficiently larger, by a factor of 10, than that obtained using existing seat suspension design methods, or from previous optimal suspension studies.

New innovations are definitely required to replace or improve the existing protection technologies, perhaps something like the tunable active vibration absorber (Scuria-Fontana 1994), being developed at the University of Connecticut, that allows a vibrating absorber to suppress another set of oscillations produced while driving, can be incorporated into new seat designs, so as to have a cancelling out effect. This principle has been used with some success on another type of vibrational energy, noise, where ear protectors actually give off a sound that effectively cancels out the environmental noise and protects the ears against noise induced hearing loss.

Some other innovative work still in its infancy in the United Kingdom is being conducted with regards to the development and installation of a swivel seat on forklifts and other vehicles, so as to reduce the risks associated with awkward twisted postures often assumed by drivers in order to reverse drive a load to its destination because of a tall load obscuring forward vision.

2.4.2.9 Active Real-Time Vibration Measurement Systems

One of the latest innovations to become available, is a portable device that can measure and analyse whole-body vibration immediately providing results on exposures. (Liberty Mutual Research Centre for Safety and Health in Mass. USA. available on-line at URL:http://www.libertymutual.com/research/news/releases/press_a.html.) This device has been used to measure the effectiveness of a new driver seat in a specific truck and to test various adjustments for that seat to find the most effective damping settings. According to the manufacturers the meter allows measurements of combined tasks since drivers often do more than one task per day. For example, if a driver makes deliveries in the morning and then operates a forklift in the afternoon the vibration "dosimeter" can take measurements from both vehicles, combine the results, and determine what the drivers typical daily vibration exposure is as well as the contributions of each individual task or vehicle.

This device may hopefully allow a breakthrough in the quest to ascertain dose-response relationships and develop better risk limits, thereby allowing better control of exposures and protection of drivers. If shown to be a valid and reliable instrument it may lead to the equipping of commercial vehicles (especially forklifts) with a vibration meter that will trigger an alarm to warn the driver when exceeding the exposure limit and to change to another task. This type of direct measurement and analysis may therefore allow future controls to be more personal to the drivers at risk.

It can be seen from the foregoing that active research is still taking place and it may still be some time before some of the new technological breakthroughs actually become marketable products. But as was discussed earlier many other controls and interventions available today can be implemented and used if they are demanded by the purchasers and drivers of these vehicles, in order to reduce the overall vibration exposures and risk factors.

2.4.2.10 Driving Surfaces

Driving surfaces have a large role to play in the production and transmission of vibration, and controls for the vehicle alone would be inadequate if the vehicles have to still operate on uneven, potholed and poorly maintained surfaces. Thus any vibration control programme will have to attend to this aspect and try and ensure a smooth driving surface and an ongoing maintenance programme to ensure the resurfacing of damaged and worn operational areas. Where uneven areas are found that need to be crossed by forklifts like railway lines and drains, some type of level crossing point would need to be designed and installed for drivers to use as a level crossing of such obstructions and thereby reduce vibration levels and eliminate the shock components of the exposure.

2.4.3 Administrative Controls

Administrative controls need to be considered with the aim of reducing exposure time, and could include the implementation of work-rest regimens, work planning and variation of tasks.

Pre-work exercise/stretching programmes as part of a full ergonomics programme to ensure driver health and safety could be implemented. In a recent article, by Bracko (1998), it was mentioned that the benefits of the pre-work warm up can be classified into three groups, physical, psychological and sociological. The physical component of warm-up complies with the concept that a warm muscle is less susceptible to injury and functions more efficiently. Exercise and stretching may have to be done more often for occupational drivers, as the spinal column requires dynamic movement, especially whilst sitting for long periods, to allow the inflow of nutrients necessary for growth and repair. In terms of injury prevention, it is the warm up that prevents injuries rather than the stretching exercises. Warm up is extremely important in the prevention of back injuries, especially injuries to the intervertebral discs (Bracko 1998).

Psychologically a pre-work warm-up can focus the workers attention on his/her job and enhance awareness of safety and injury prevention. This psychological aspect may be the most important component of the pre-work warm-up. The sociological aspect encompasses a team concept that will allow better moral and productivity amongst employees. In his article he gives the example of a programme implemented in a saw mill in Canada, where their was a definite measurable decrease in injuries, but also the injuries that did occur were less severe.

Training and education programmes designed specifically for forklift drivers need to be developed to make them aware of the risk and ergonomic factors at play, and to alert them as to how to minimise negative effects. The importance of exercise, rest, posture, twisting, stooping and other risk factors need to be highlighted, in any programme to enable the drivers to understand the risk and exposure characteristics and take adequate precautions to protect themselves. A full understanding of the importance of the adjustment of seats for weight-vibration damping, should also be included in any training programme to ensure the best possible use of the damping systems available. Ergonomic design features are beneficial only when used properly. Drivers need to understand the importance of proper seat adjustment and exercise, as well as all other issues discussed earlier that are critical to the safe operation of forklifts and reduction of vibration exposures and effects.

2.4.3.1 Medical Monitoring and Pre-employment Testing

Pre-employment screening and periodic medical examinations of drivers to identify susceptible individuals and detect musculo-skeletal problems at an early stage may be a useful strategy and is commonly used in other industries for a wide range of occupational groups exposed to various industrial hazards. In a pilot study conducted at the public passenger transport authority, Transperth in Perth, Western Australia, various methods of pre-employment clinical and physical tests where used including::

Abdominal Isometric Hold at 50 Degrees;
Partial Situps;
Bilateral Leg Lowering;
Back Extensors-Isometric Hold and;
Dynamic Back Extensions. (Summers 1991)

These tests were selected from other studies in the literature that had developed and tested trunk muscle strength isometrically, concentrically or eccentrically. A questionnaire was also used to gather back pain histories, and then a full medical examination was performed. The measures mentioned did not have a quantatitive basis and were more qualitative in nature.

It was found that those that failed the physical testing were also those that performed poorly in the medical examination, and medical practitioners indicated that the information derived from physical testing was a useful adjunct to their own assessment. However, the usefulness of either screening tests, or pre-employment medical examinations for predicting back injury has not been convincingly demonstrated. The role of pre-employment screening to detect individuals with a high risk of back injury may be a useful tool, but requires further testing before widespread implementation, to assess its efficacy and to ensure the practice does not become discriminatory and cause other labour relation problems. Due to the problems and difficulties in making specific diagnosis of back related problems and disorders, caution needs to be exercised when classifications of back conditions are made in order to ensure correct action is taken as far as employment placements and activities of professional drivers is concerned.

2.4.3.2 Health and Safety Policy

In order for any whole-body vibration control and worker protection programme consisting of many components to be successful, a full management programme needs to be drafted and implemented that will ensure commitment from all involved, from top management to the employees, as well as the eradication of ambiguity, so everyone knows their responsibilities and they can be evaluated and measured to ensure success. Such a programme would contain components such as written policies and operating procedures, organisational responsibilities, equipment selection and maintenance, risk assessment and evaluation of vibration exposure areas, implementation and evaluation of control measures, and an ongoing programme evaluation component to assess the effectiveness of the programme against set norms and standards. It is important to integrate the vibration health and safety policy into the organisations general health and safety policy so it becomes an integral part of the workplace policy on hazard control and not a stand alone component. All possible control measures should be considered and applied in an integrated manner to ensure adequate control of any vibration hazard.

2.5 FINAL CONCLUSIONS AND MOTIVATION FOR THE STUDY

From the evidence presented in this and the preceding chapter it can be concluded that long-term whole-body vibration exposure during professional driving, can lead to adverse health effects primarily in the musculo-skeletal system, notably the spinal column, vertebrae and intervertebral discs, as well as other non-specific effects on other organs and systems of the body. Numerous co-factors may modify these risks The data therefore present a case for the designing and implementation of better tested and scientific control and prevention strategies and measures to address this exposure and reduce the adverse health effects experienced by those exposed.

Not all control measures will be practical or available in every situation, but a holistic view has to be considered when addressing this problem. The most innovative design will remain ineffective if the co-operation and motivation of the employer and employee are not secured, so they can start to demand protection from their forklift suppliers and government in the form of the drafting and enforcement of appropriate legislation.

In particular the use of back belts for reduction of symptoms of whole body vibration exposure remains an unproven preventive strategy and more emphasis and attention must be paid to controls at the source. Control of whole-body vibration should follow the standard hierarchy of controls using the sound fundamental principles of engineering, and administrative control measures first, and not the "quick fix" route as is so common in South Africa.

The literature indicates that the problems of whole-body vibration are as prevalent today as they were in the past. With South Africa being a country undergoing much political, economic and social change, we find many unique aspects that have an influence on our particular occupational environment and workforce, and the attitudes, beliefs and behaviour regarding industrial hazards.

Given the unsubstantiated use of back belts by professional drivers in industry in South Africa, it becomes important to investigate the effectiveness of these devices and their impacts on workers health. Thus this research study encompasses an evaluation of risk factors associated with back pain in forklift drivers subjected to whole body vibration exposure, in order to establish the effectiveness of the use of back belts in reducing the prevalence and severity of back pain

This study will hopefully highlight the situation with regards to the use of these belts by professional drivers, but it is hoped that it will also bring the potential hazards posed by whole-body vibration into the spotlight and stimulate greater awareness and implementation of controls in industry.

This will not only benefit the drivers themselves who have been a neglected occupational group, but the employers as well when they have a happier workforce, reduced absenteeism, medical costs, injury rates and increased productivity.

The data from this study could be used to motivate for a healthier, safer and more productive working environment for forklift drivers, by stimulating the investigation for some sort of legislative control like regulations, and also perhaps be the basis for further employer and employee guidelines and training documents.

CHAPTER 3:
RESEARCH METHODOLOGY AND STUDY DESIGN

"Everywhere our knowledge is incomplete and problems are waiting to be solved. We address the void in our knowledge, and those unresolved problems, by asking relevant questions and seeking answers to them. The role of research is to provide a method for obtaining those answers by inquiringly studying the facts, within the parameters of the scientific method." (Leedy 1993)

This chapter serves to discuss and describe the study environment at Portnet and the background to the study. It goes on to cover the planning of the empirical research, the study design and the study population, methods of data collection and analysis, as well as field work. The all-important considerations of the handling of bias and confounding factors are also addressed in some detail.

3.1 THE STUDY ENVIRONMENT (Portnet)

This study was conducted at Portnet, Durban, in response to the number of complaints received in 1996 from forklift drivers, regarding the problem of lower back pain and other musculo-skeletal injuries, as well as due to the excessive number of days being lost due to sick leave, and back injuries. A small pilot study (n=120) carried out in the Point area in May 1996 by the risk officer in charge, showed 15 drivers were absent in the month of May due to back pain, with a total of 47 driving days lost due to back pain amongst this occupational group.

The researcher approached the risk management section and union representatives in March 1996 and requested access to conduct the study to investigate the extent of the problem, the risk factors associated with forklift driving and the operational environment and to investigate the potential control measures that could be implemented.

The port of Durban falls under the authority known as Transnet, with Portnet being a business unit that controls the harbours of South Africa. Portnet Durban consists of three main operational areas, namely: Point, Maydon Wharf and Combi Terminal (pier 1.), each area has its own business unit manager and runs as a separate unit on its own.

and other parts of the body.

However the forklift drivers also work on an unofficial piece work system, where it has become a norm that drivers can go home early if they complete the work allocated for the day in a shorter time period. This is thought to not only increase productivity, and is acceptable to the drivers, but is a factor that will increase the vibration exposure levels and associated health effects too, with the increase in driving speeds, associated vibrational shock loads and reduced rest periods.

At Portnet the forklift drivers do not have to lift loads manually, as they have other workers at the site that help to manoeuvre loads when necessary and most loads of cargo and break bulk is off-loaded on pallets that allow ease of lifting by forklifts. An increase in the risk of back injuries may result when the drivers of LPG gas powered forklifts specifically have to change the gas bottles on the back of the forklift when empty. However LPG gas powered forklifts are in the minority at Portnet with diesel being the predominant fuel used that does not require manual lifting. When new LPG gas bottle is needed another forklift is used to lift the bottle to the required height for replacement, thereby reducing the risk of back and other musculo-skeletal injuries.

With an increase in workloads at the port and the time constraints experienced during heavy ship traffic, drivers are required to move loads as fast as possible so the next ship can berth. This results not only in increased driving speeds, but also in an increase in the loads carried on each trip. This also results in tall loads being carried, where the driver cannot see over the load in front of him on the forks, forcing him to drive to his destination or off-load point in reverse looking backwards over his shoulder. The twisting motions that are experienced are as a result of the twisting of the neck and upper torso, so that they can see where they are driving. This motion is fortunately not a common practice under normal operating conditions, but it could have a greater effect on the spinal column when coupled with vibration exposures.

At Portnet the forklifts are usually parked outside and are open to the elements on the wharf side, with exposure to salt laden air, rain and wind. Thus it is common to find that corrosion of the seats is quite severe, and due to lack of maintenance and lack of use the seat adjusters for both weight-damping and fore-aft adjustments are often corroded and stuck in one position. When the study was conducted some of the seat adjusters had to be moved with vice-grips to adjust the seat for weight, indicating the seats are very seldom or never adjusted by the drivers.

Many different types, makes and models of forklifts are used at Portnet over a range of different load capacities, from 3 tons to 40 tons. Due to the increasing costs of forklifts they are often kept in service for extended periods of time. Many of these older types of forklifts are still in daily use at Portnet and have inadequate seating, with poor ergonomic design and almost no vibration damping abilities. The seat is bolted directly to the floor or chassis of the forklift and has no adjustment for weight or vibration damping, but relies on the foam rubber cushioning of the seat to offer attenuation and protection. These older types are fortunately being phased out with more modern forklifts being added to the fleet.

Many of the driving surfaces found in many areas of Portnet, especially on the wharf sides, where the traffic and volumes of work and cargo handled has increased over the years, has resulted in badly damaged surfaces that in some places has not been retarred or maintained in 20 years.

During the planning phase of this study (early 1997), where it was planned for different interventions to be tested for effectiveness, a request from the unions at Portnet was made to the risk management section in two of the three areas for the issuing of back belts to all drivers to reduce or "prevent" the lower back pain being experienced by them. The drivers and union members were requested by the risk management section at Portnet to wait until the intervention study originally planned by the author had been completed. It was intended that when all risk factors had been identified and relationships evaluated in the original study, then further implementation of identified interventions, such as the installation of better seats, resurfacing of driving surfaces etc would take place in order to find the best solution to the problem.

However, drivers insisted on the issuing of back belts and Portnet risk management issued the belts to all drivers in two of the three areas (Point and Maydon Wharf) in December 1996, before the present study officially started. The idea of a before-after study with a base-line was therefore not possible given that at that stage, the project was still in the process of developing its questionnaires. However, because the third area (Combi Terminal), geographically isolated from the other two areas did not receive the back belts it was possible to observe a natural experiment with two groups with similar exposures, operating conditions and characteristics presenting themselves for study, the main difference being the introduction of the independent variable, the back belts. The questionnaire administration officially started 10 months after the belts had been issued, on the 21 October 1997 and was conducted for a period of 12 months till the 17 September 1998. Back belt usage by the drivers still continues at Portnet at the two sites, Point and Maydon Wharf.

The drivers and other employees at Portnet provided some very important and relevant information from the field. With their greater insight into some of the specific organisational problems, operational conditions and specific beliefs and practices amongst the drivers many of these important and relevant issues were brought to the researcher's attention, most of them not being available or even mentioned in any literature or other source. Other relevant information was provided by the manufacturers of forklifts upon questioning, who offered the latest manufacturing and vibration control technology information, as well as the expertise of their mechanics and technicians who were questioned to gain an insight into the operational and maintenance considerations necessary for proper forklift operation, maintenance and protection of workers. This was all invaluable in the planning of the research study and when relevant factors were identified that needed consideration in the planning stages.

3.2 PURPOSE, AIMS AND OBJECTIVES

3.2.1 Purpose

To characterise the problem of back pain amongst forklift drivers with a view to reducing the morbidity from back pain, by evaluating the effectiveness of the use of back belts.

3.2.2 Aim

To identify risk factors associated with back pain amongst forklift drivers at Portnet in two groups of forklift drivers one using back belts and one control group, and to evaluate the relationship between back pain, the occupational environment (ie: forklift driving) and other associated factors, in order to establish the effectiveness of back belts in decreasing the severity and prevalence of back pain amongst forklift drivers.

3.2.3 Objectives

1.) To describe demographic and other relevant risk factors for back pain in the two groups and to identify any significant differences between them. They include:

- Age
- Exercise, sports and other activities
- Occupations prior to driving at Portnet
- Driving speeds
- Rest breaks taken during shifts
- Other control measures used
- Onset of back pain after starting driving if any

2.) To characterise the compliance and frequency of use of the back belts by the user group.

3.) To measure vibration experienced in typical driving activities in the study population in order to characterise semi-quantitatively the intensity of whole-body vibration exposures of the study subjects to use these data to develop one or more exposure matrices for drivers in the study.

4.) To ascertain opinions and beliefs regarding back belts amongst users.

5.) To determine the prevalence, severity, duration, location and chronicity of back pain including lower back pain amongst forklift drivers.

6.) To determine if any significant differences exist between the two groups as to the prevalence and severity of back pain including lower back pain, and what factors are associated with increased risk of back pain. Specifically to identify whether (a.) The frequency and /or intensity of use of back belts are associated with reduced risk for back pain, when controlling for all other relevant risk factors, and (b.) Whether other factors confound or modify this relationship.

3.3 DEFINITIONS

A short list of key definitions is presented below:

3.3.1 Back pain: Any acute or chronic pain, ache or stiffness experienced by the worker in any part of the back, excluding the shoulder area.

3.3.2 Lower back pain: Any acute or chronic pain, ache or stiffness experienced by the worker in the lumbar region of the back. This includes the terms lumbago and chronic recurrent discomfort in the lower back/lumbar area but excluding sciatic pain radiating into the legs.

3.3.3 Beliefs: A belief is a statement about the attributes or characteristics of an object, person, the world etc, that an individual thinks is true. A person may, therefore believe that the back belts are effective in preventing or reducing back pain. Such a belief may in turn lead to an attitude about a particular object.

3.3.4 Attitudes: An attitude is a learned orientation or disposition towards an object or situation which provides a tendency to respond favourably or unfavourably to the object or situation. The response to an object or situation results from an evaluation which expresses the persons attitude towards it. These evaluations are expressed in terms of liking/disliking, favouring/not favouring, pro/anti, and positive/negative. A given attitude is often a summary of evaluations made of different aspects of the attitude object.

If a person believes that back belts are too hot and uncomfortable to wear, and in fact do not effectively reduce the pain, he/she may develop a negative attitude towards the belt. A belt wearer that believes the belts are comfortable and do in fact reduce or eliminate the back pain during or after driving, will have a positive attitude.

An important property of attitudes is that they may guide behaviour, for example avoiding something or inducing a person to act in a certain manner. In the above examples, a negative attitude towards back belts may induce the person to stop using it, and a positive attitude will induce a person to continue wearing the belt whenever necessary.

3.3.5 Opinions: An opinion is a verbalised attitude, an in this case it is hoped that the questionnaire responses would allow this expressing of "attitude" and therefore the opinion of the drivers on various aspects of the belts and their use.

For a more comprehensive list of definitions see Appendix A.

3.4 STUDY DESIGN

> *"The experimental/observational method deals with cause and effect. We try to assess the cause and effects dynamics within a closed system of controlled conditions, which vary from highly closed and strictly controlled situations as in a laboratory experiment, to field studies where control of variables and effects is more difficult."* (Leedy 1993)

The study at Portnet presented an opportunity for a "natural experiment" where an intervention was implemented on the request of the unions and drivers in the form of back belts, but were only used in two of the three operational areas at Portnet, allowing a test "intervention group" (Point and Maydon Wharf) to be compared to a control group (Combi Terminal). Another important factor was that they were separated from each other geographically, thereby reducing the likelihood of contamination of the control group (the use of back belts by the controls). On a whole the two groups were fairly homogenous being from the same occupational group (forklift drivers), with similar characteristics and operational conditions, as well as being closely matched demographically in that they were all male, and mainly of one race group (black). The groups also shared the same socio-economic status, due to the fact that they are employed by the same company, receive one standardised pay rate and have the same access to health care through the company clinics and health benefits system. Comparisons could therefore be made and multivariate analysis carried out to assess similarities and differences.

This research design known as the quasi-experimental design (Leedy 1993:302), is described in epidemiological literature as an observational design. (Lilienfeld and Stolley 1994:226) Brink (1996:11), has shown that the Quasi-experimental design's main purpose is to test hypotheses

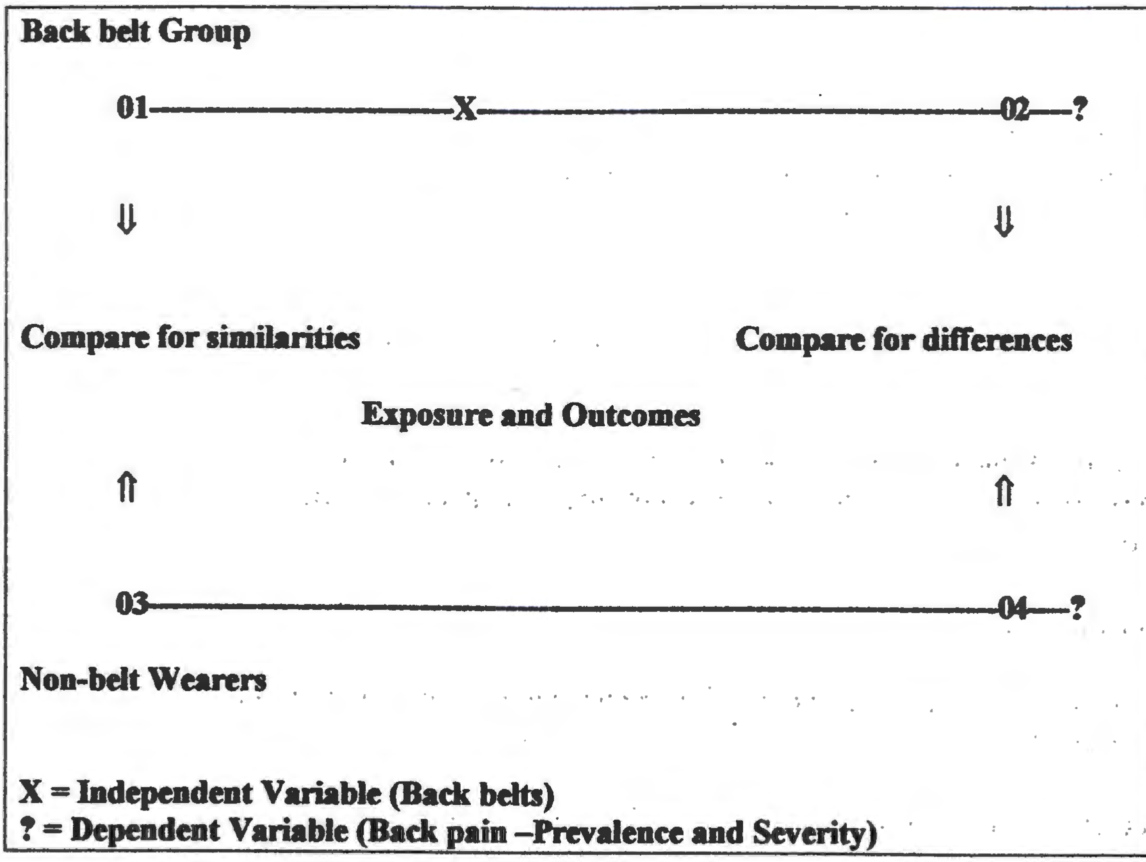
For the Portnet study, a cross sectional study design was chosen from possible observational designs.

The cross sectional study design is one of the more widely used observational methods, and is used in situations where random assignment of subjects to an intervention is not possible and where follow up (cohort designs) are not possible.

A cross sectional study is one where a sample of the population is selected and information is obtained simultaneously on exposure and outcome to determine wether persons with a particular exposure characteristic are more likely to have the outcome (disease or condition) being investigated. The outcome of interest may be adverse (morbidity or mortality) or beneficial (protection from morbidity or mortality). In the latter case, the exposure is evaluated for its effectiveness in preventing death or disease. Prevalence or death rates for the disease or condition can then be calculated , and the rates are then compared for those with the characteristic of interest and those without it. If the rates are different , an association can be said to exist between the characteristic and the disease or condition (Lilienfeld and Stolley 1994:198).

Observational study design differ from an experiment in that the subjects select themselves for exposure or non-exposure. The exposure is not allocated under the control of the researcher and the researcher can only observe the outcomes associated with the individual exposures experienced by participants in the study.(see figure 3.2) This renders the study vulnerable to bias.

Figure 3.2 Observational (cross-sectional) research design.



In the Portnet study each group selected themselves into exposure categories by choosing to adopt back belts as a protective device. By comparing groups after the "intervention" for a reduced prevalence and severity of lower back pain and other outcomes amongst the two groups of forklift drivers, an assessment of effectiveness may be made.

In the Portnet study this was done as a cross sectional study, where the data on outcomes and exposures were collected simultaneously after the exposure had taken place.

3.5 POPULATION AND SAMPLING

3.5.1 Population

Forklift drivers are required to undergo a licensing process to obtain a drivers licence and thereafter they are required to undergo a bi-annual accreditation process to remain registered as a forklift driver and maintain a current licence status. This process is managed by the South African Institute of Materials handling who have records pertaining to the number of forklift drivers accredited and licensed to drive in South Africa.

The manager of the accreditation division of the Institute, Mr Johan de Klerk in a personal communication with the researcher stated that there are approximately 60 – 70 000 accredited and licensed forklift drivers currently on their books and he estimates a further 10% of drivers above these figures operate without licenses, making the estimated total number of forklift drivers not including other types of professional drivers close to approximately 90 000 or more.

3.5.2 Definition of the Research Groups

The study population comprises all drivers of 3, 4, 4.5 and 5 ton forklifts in the permanent employment of Portnet Durban as at December 1995. The final sample included all drivers present and available on the days of the questionnaire administration, i.e.: 20 separate days (see table 3.1) were set aside over the research period, with a total of (291 people) working as forklift drivers in the three main research areas included in the study at the Port of Durban, namely Point (105 drivers), Maydon Wharf (55 drivers) and Combi Terminal (131 drivers). The research project did not include any of the other drivers classified to drive vehicles other than forklifts such as reach stackers and container handling vehicles.

The back belt group was made up of drivers from the two areas, ie: Point and Maydon Wharf, where back belts were issued and used as a protective device against back pain. The non belt wearing group was made up of drivers from the third area, Combi Terminal, where back belts were not issued nor worn by drivers.

Sample size calculations estimated the number of participants needed based on the following assumptions:

1.) A 90% prevalence of back pain in the control group based on the pilot study;
2.) a 95% probability (1 - α) and;
3.) 80% power (β).
4.) a sensitivity analysis for 20 - 50 % reduction in back pain as a result of the use of back belts;

Given these assumptions the full sample intended of 160 exposed drivers and 131 controls would achieve sufficient power to detect a 17% difference in prevalence in the two groups. Smaller samples would have power to detect larger differences only as indicated in the table. The final sample successfully recruited (158 exposed and 51 controls) was of a size sufficient to detect a 23 % change in prevalence from a baseline of 90 %.

Table 3.2: Sensitivity table applicable to the sample size selection.

Sample Size Control	1:1 Exposed	1-Alpha (α) 95%	Beta (β) 80%	Prevalence 90%	Change in Prevalence %
71	71	95	80	90	20
38	38	95	80	90	30
24	24	95	80	90	40
17	17	95	80	90	50
Sample Size Control	**1:2 Exposed**	**1-Alpha (α) 95%**	**Beta (β) 80%**	**Prevalence 90%**	**Change in Prevalence %**
56	111	95	80	90	20
30	59	95	80	90	30
18	37	95	80	90	40
Sample Size Control	**1:4 Exposed**	**1-Alpha (α) 95%**	**Beta (β) 80%**	**Prevalence 90%**	**Change in Prevalence %**
47	188	95	80	90	20
***38**	**151**	**95**	**80**	**90**	**23**
25	99	95	80	90	30
16	62	95	80	90	40

* Sample size achieved for the Portnet study.

3.5.3 The Sampling Procedure

The sampling procedure aimed for a 100% sample in all three areas, taking into account all the different shifts and schedules as well as leave cycles and absence for training or illness. Thus the questionnaire administration was conducted over many months, from October 1997 to September 1998, to enable all drivers to have an equal chance to complete the questionnaire, and to accommodate those on unusual shifts.

With regards to the sub-study needed to characterise the vibrations of the forklifts, a sample of 9 forklifts were purposively chosen. Forklifts of various models and designs were selected on the day of the measurements as they became available for testing under the various operational conditions (rough and smooth), and the various seat adjustments. A stratified sample was preferable, but due to time and logistical constraints and other problems on the days of the measurements it was impossible to comply with this. (See section 3.8 for more detail on vibration measurement pilot sampling procedures.)

3.5.4 Inclusion and Exclusion Criteria

Inclusion and exclusion criteria were also employed as a measure to exclude as many confounding variables as possible.

Drivers from the two groups were included according to the following criteria:

1.) Subjects had to fall into the Class 2 driver classification at Portnet, thereby allowing them to drive a certain class of forklift. Drivers from other classes were excluded from the study, and did not fill out the questionnaire.

2.) Only the smaller vehicles of three (3) ton, four (4) ton, four and a half (4.5) ton and five (5) ton forklifts were included. Drivers of the larger forklifts and other vehicles were excluded as they formed a smaller subgroup of the total driving population and some of the vehicles were not used in all of the three areas, and their vibration exposure would not be comparable across the three areas.

3.) Drivers who had received belts but had never worn them were however still included in the study.

4.) Drivers in the control area, Combi Terminal, who had bought and worn their own back belt were excluded, as other extraneous factors and motivations could have played a part in this decision, such as a higher level of education, more pain experienced, or personal opinions that would not have been found in general amongst the rest of the drivers in the control group area of the study. (This only applied to two of the drivers from that area.)

5.) Workers had to have been drivers for at least 12 months prior to the study. After the data collection it was ascertained that a few drivers in each of the areas that had completed the questionnaire were in fact casual drivers and not in the permanent employment of Portnet. These workers were excluded.

6.) Drivers who had previously had any type of back operation were also excluded from the study.

Drivers who did not use belts for reasons, such as choice or other personal reasons were included in the final analysis as they had an opportunity to wear the belt Their responses as to reasons for non-compliance were however noted and included in the multivariate modelling as they represented a small subgroup of the back belt group and could perhaps offer valuable insight into other factors concerning the problem under study.

3.5.5 Representativeness

Although the choice of Portnet drivers as the sample was not based on any probabilistic sample of forklift drivers in general, and as such, cannot be truly representative of the population of forklift drivers in South Africa, the profile of drivers is fairly typical of this category of worker. There is no reason to suspect that Portnet drivers were particularly unusual in key risk factors. For this reason, the results from the sample may be taken as broadly representative of the sector, although generalisation should be done with circumspection.

3.6 MEASUREMENT

3.6.1 Methods Of Data Collection

Data was collected by using a validated, standardised questionnaire, in English and Zulu translations. In addition, vibration exposure was assessed in a pilot study with vibration measuring equipment as per the ISO 2631 (1997) standard. This is discussed in more detail later in the section describing the pilot study.

3.6.2 Questionnaire

A validated questionnaire based on the Standardised Nordic Questionnaire for the Analysis of Musculoskeletal Symptoms, (Kuorinka *et al*, 1987) (See Appendices D and E) was used in the study. Additional questions were added to adapt it to the operating conditions at Portnet including the different areas, shifts, rest periods and forklift types. To increase the number of risk variables other questions were added such as sporting and other extra mural activities, as were questions on the knowledge, attitudes and opinions of drivers on various aspects of their occupation and working environment. These questions were necessary to make the questionnaire more applicable to the actual conditions and situation at Portnet, and to ensure the usefulness of the survey to Portnet risk control section.

The questionnaire was used for both exposure and outcome assessment, as well as for quantification of potential confounders. Comparisons were then made for differences, that would enable the outcomes on the two groups to be quantified, as to the effects of the independent variable, back belts on the dependent variable, the back pain.

Table 3.3.1: Categories of questions included in questionnaire and variables addressed regarding demographic data and exposure to back belts.

DEMOGRAPHIC DATA	Similarities/Differences	Comments
Age	Age	
Race	Race	
Occupation before driving	Prior Occupations	Previous Exposure
Work Area	Work Area	Back Belt Users or Controls
Type of Forklift Driven	Forklift Types	Old or New Types
Rest Breaks Taken	Breaks Taken	Data not Used (Invalid)
Sports	Sporting Activities	Identified Protective/ Risk Factors
Other Activities	Sedentary and Non-sedentary Activities	Identified Protective/ Risk Factors
Back Belt Use	Compliance with Use	Used as Exclusion Criterion for Controls.
Other Control Measures Used	Other Control Methods Used	Used to Identify Potential Confounders

Table 3.3.2: Categories of questions included in questionnaire and variables addressed regarding back pain and symptoms experienced.

BACK PAIN AND SYMPTOMS	Similarities/Difference	Comments
Pain or Stiffness in Back	Lifetime Prevalence	
Year of Onset of Back Pain	Onset after Starting Driving	Pain after Exposure
Site of Pain	Pain Location	Differentiated LBP
Pain Today	Point Prevalence	
Pain in Last 12 Months	12 Month Prevalence	
Pain after Driving Forklifts	Occupational Exposure	Linked to Forklift Driving
Sick Leave in Last 12 Months	Absenteeism	Data not Used (Invalid)
Pain Duration	Duration of Pain	Acute or Chronic
Pain Intensity at Least	Pain Severity	Pain Severity Scale
Pain Intensity at Worst	Pain Severity	Pain Severity Scale
Treatment for Back Pain	Treatment Sought for Back Pain	More Specific Outcome
Medication taken for Back Pain	Medication taken for Back Pain	More Specific Outcome
Previous Back Operations	Back Operations	Used as an Exclusion Criterion

Table 3.3.3: Categories of questions included in questionnaire and variables addressed regarding the vibration exposure.

VIBRATION EXPOSURE	Similarities/Difference	Comments
Number of Years Driving Forklifts	Lifetime Exposure Period	Related to Vibration Dose/ Exclusion Criterion
Number of Hours Driven per Day	Hours of Exposure Per Day	Data not Used
Adjustment of Seat	Use of Existing Controls	Compliance with Use
Driving Speeds	Opinions of Driving Speeds	Related to Vibration Exposure

3.6.2.1. Exposure Assessment

The assessment of exposure to back belts was primarily based on a dichotomous category of exposed versus control cohorts ie: group exposure. A second exposure metric was based on the frequency of reported usage of back belts by individuals.

Attribution of individual exposure to the whole-body vibration dose received by each driver could not be estimated because of variations in work practices, different vehicles used and the absence of accurate exposure periods in hours. As proxy for vibration exposure, years worked as a forklift driver was used. Questions relating to the exposure duration, drivers opinions on driving speeds, rest breaks taken during shifts, and other control measures used and their effectiveness were included in order to allow better characterisation of vibration exposure.

3.6.2.2 Outcome Assessment

The outcomes of the study to be assessed were also questionnaire based and were used to quantify the major health impacts associated with forklift driving (exposure) and the use of the intervention device (back belts). The major outcome that was assessed in various ways was the occurrence and experience of back pain which is defined as any acute or chronic pain, ache or stiffness experienced by the worker in any part of the back, excluding the shoulder area.

The major outcomes that were assessed were:

1) Onset of back pain after starting driving: Question included to ascertain how long the musculo-skeletal symptoms of back pain took to develop after the driver started in his new profession. This is defined as the number of years or months after starting to permanently drive a forklift that back pain developed.

2) Prevalence of regular back-pain (ever): This outcome was used to compare the general prevalence of back pain amongst the two groups to identify if any differences existed. This is defined as back pain experienced at any time in the past.

3) Point prevalence (pain today): This outcome was used to ascertain if the respondent had back pain on the day of the questionnaire administration. This is defined as back pain experienced on the day of the questionnaire administration.

4) 1 Year prevalence: This outcome was used to ascertain the prevalence of back pain over the intervention period in order to see if the intervention (back belt group) differed significantly from the control group. This is defined as back pain experienced at any time

in the last 12 months.

Because the indirect methods suggested by the authors of the Nordic questionnaire seemed to be open for misinterpretation a pain severity rating scale was included as a separate section in the questionnaire to allow the severity and chronic or acute nature of the pain to be rated. To achieve a greater degree of precision in measuring intensity of back pain, use was made of the 101-numerical rating scale (Jensen, Karoly and Braver, 1986).

5) Severity of back pain: These outcomes derived from the 101-numerical rating scale allowed comparisons to be made between the groups as to the severity of the back pain, as well as the chronic or acute nature of the pain experienced and to identify any significant difference in the belt wearers. This scale was modified slightly for the Portnet study, as the scale was used twice instead of the usual once , in two separate questions one that covered the pain intensity level when it was at its most intense, and one that covered the pain intensity level when it was at its least, in order to gain an insight into the acute or chronic nature of the back pain experienced by the drivers. It was decided to use the questioning scale twice as it allowed a clearer discerning of the severity of the pain experienced, as each scale offered information on severity alone, but when compared to each other they offered a clearer picture as to the chronic and acute nature. (See appendices D and E for questionnaire)

6) Duration of pain: This outcome indicated how long the pain usually lasted after driving had stopped. This is defined as the length of time in hours, days, weeks or permanently that the back pain is experienced by the driver after driving a forklift.

7) Treatment/medication for back pain: These outcomes were used to ascertain if the two groups differed in their seeking of medical attention for back pain, both from traditional and non-traditional sources. This is defined as the seeking of medical treatment from traditional and western medical practitioners specifically for back pain and the consumption of/or application of medication to the body specifically for back pain. This outcome was also regarded as a proxy for severity of back pain.

8) Absence from Work: This outcome was originally to be used to enable comparison to be made between the groups as to whether or not the absenteeism rate had dropped significantly, in the intervention belt wearing group. (However, because it relied on self reported absenteeism data and the memory of the respondent it was excluded from final analysis.) This is defined as any absence from work for one day or more due to back pain. This outcome was also regarded as a proxy for severity of back pain.

3.6.2.3 Other Factors

The final short section concerned back belt use. Attitude questions were developed based on the significant parameters cited in the literature, most notably concerning compliance, patterns of use, heat friction, skin irritation, and general discomfort. Further questions were added on the advice of key informants covering aspects such as the fit and quality of the belts as well as beliefs about the use. These questions were also reviewed by union members, health and safety professionals, a statistician and other interested parties before implementation to ensure acceptability, relevance and applicability. This was developed *de novo* as a stand alone questionnaire as no other questionnaires regarding the use of these belts for this purpose could be found. These questions included:

- Aspects on the compliance and frequency of use of back belts;
- Back belt users opinion on effectiveness;
- Statements regarding beliefs and opinions regarding the use of back belts.

3.7 The Questionnaire Administration Process

The questionnaire was administered to the respondents in groups, by the trained Zulu speaking Risk Officer with the researcher in attendance in order to offer any assistance required. The researcher addressed the participants prior to the administration of the questionnaire, in order to explain the background, nature, aims and objectives of the study and to answer questions from the respondents or clarify points raised.

All respondents were informed with regards to the anonymity and confidentiality of the data in the questionnaires, and signed informed consent was obtained from all participants, by signing on the front page of the questionnaire where all instructions and consent issues appeared in English and Zulu. (Appendices D and E) The front page was then detached in full view of each respondent and put in a separate pile away from the questionnaires to ensure complete anonymity as discussed with union representatives before the study.

Fully literate respondents were then instructed to complete the questionnaire on their own at their own pace, with instructions that they could ask questions or for clarification on questions at any time. The illiterate and other drivers that preferred to participate with the group were then taken through the complete questionnaire by the translator, question by question, reading each question in Zulu and explaining and answering any questions, with the following question being answered only when everyone had completed the question being discussed.

This procedure was followed to ensure that no questions were left out, no-one got frustrated by being left behind, or embarrassed by being unable to complete the questions themselves. The researcher and assistants moved around the room helping individual drivers fill in the questions with interpretation help from the translator.

3.7.1 Practicalities of the Field Administration

The questionnaires were originally intended to be administered at a monthly driver's meeting, where it was indicated that all drivers in a particular operational area met on a regular basis. However on further investigation it was discovered that only union representatives and shop stewards met at the monthly meeting and then returned to their individual workplaces for feedback to the other drivers.

Another system of administration was then tried where the researcher, interpreter and assistants went out to the operational area and stopped individual drivers in order to explain the process, and administer the questionnaire on site. However, this was unsuccessful due to the mobility of the drivers, the unfavourable circumstances with regards to work schedules, and environmental conditions such as noise and heat encountered at the port. It was also not practical to administer the questionnaire to individual drivers, due to time constraints and logistics.

It was then planned that the risk officers from each area would contact the berth managers at each part of the port and brief them on what was required, from a logistical, planning and time perspective to allow all drivers in a particular area to be able to attend a specific venue in order to complete the questionnaire. This was done in groups from 4 -14 drivers at a time. Portnet employed 10 casual drivers in two of the three areas to relieve drivers at the work site to enable them to complete the questionnaire. The third area gave drivers time off in the morning to complete the questionnaires. The venues set aside were the mess and ablution facilities, vacant offices and clinic or training facilities or rooms.

The administration of the questionnaire was carried out over a period of 12 months from 21 October 1997 to 17 September 1998, with more than 20 separate visits being made for questionnaire administration in the different areas. The questionnaires administration started 10 months after the back belts were first issued in December 1996, to enable suitable time to pass before testing, and this meant that drivers had the opportunity to wear the belts over a period ranging from 10 months to 22 months, at the end of the questionnaire administration period depending on when they filled in the questionnaire. The wearing of belts is ongoing in those areas where they have been issued.

The same questionnaire was administered to both groups, except the pages that elicited information about back belt usage was omitted from the control group questionnaire, so as not to introduce or stimulate bias in their responses towards the issuing of back belts by exaggerating the incidence and severity of back pain. Only one question (question 29) regarding back belt usage was left in the questionnaire to this group as a control question to enable identification of drivers that had bought and used the belts on their own recognisance. It was seen that this was not emphasised by the questionnaire administrator, and was grouped amongst other potential control measures used, such as reducing driving speeds and using cushions for back support, so as not to elicit a biassed response. All questionnaires in the back belt and control areas was administered by Mr Sihle Khumalo, a Risk Control Officer employed at Portnet, Durban. He was assisted by two other risk control officers from Portnet, namely Miss Stephanie Samuels and Mr Sean Du Plessis, from the areas included in the study. They attended to the logistical aspects of the questionnaire administration, namely arranging venues, liaison with management and drivers etc.

3.8 Pilot Study: Whole-body Vibration Measurements

Variations in vibration exposure between and within the experimental groups could have an influence on the outcome on the dependent variable ie: the incidence and severity of back pain amongst the drivers. For this reason vibration measurements were taken in the different areas under different conditions to validate prior assumptions about vibration exposure and to characterise the associated exposure with the different activities and areas.

A sample of forklifts from those routinely used in each of the study areas was evaluated by vibration measurements taken at the interface between the human body ie: the driver, and the source of its vibration ie: the forklift seat. The aim of this was to confirm:

a.) that factors hypothesised *a priori* to be associated with high levels of whole-body vibration (vehicle age, vehicle type, speed of driving, road surface, type of seat and adjustments), were valid proxies in the study.

b.) that for a given activity or environment variability in whole-body vibration was not excessively high.

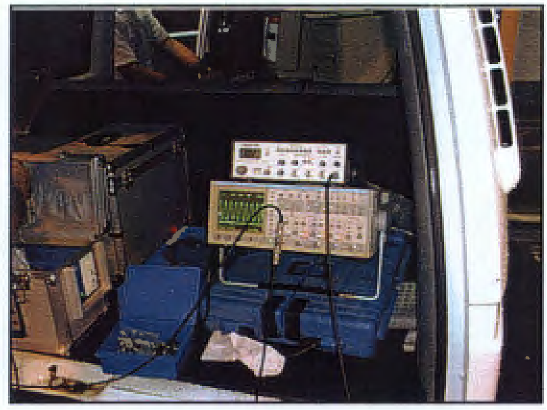
c.) that vibration exposure did not differ systematically between areas.

For the analysis and measurement of whole-body vibration in this study the ISO-2631 (1997) guideline was used entitled; Mechanical Vibration and Shock - Evaluation of Human Exposure to Whole-Body Vibration. The older version ISO-2631 (1985) guideline was not used since it is only applicable in the frequency range 1 to 80 Hz whereas the range 0.5 to 2Hz is of relevance for health effects and is covered by the ISO-2631 (1997) guideline which was recently adopted as a draft South African standard, and will most probably be accepted in the near future. It was therefore decided to use the latest guidelines in this study.

Measurement of vibration was conducted by using a Bruel & Kjaer (B&K) tri-axial piezo-electric accelerometer (Model 4322) mounted on the forklift seat in a deformable rubber disc shaped pad which followed the seat contour (see plate 1.1). In addition to the measurements on top of the seat surface an additional measurement was conducted by placing an accelerometer underneath the seat on the forklift chassis to capture data in the z-axis (vertical) plane in order to determine the transfer function of the seat. Tri-axial accelerometers measure vibration intensities and frequencies in the X (fore and aft), Y(sideways) and Z (up and Down) directions and the accelerometer charge outputs produced by the vibrational energy during the test drives were amplified using PCB model 424A accelerometer charge amplifiers, sent over a Johne and Reilholfer PCM telemetry system, and captured and stored on a remote PC station.

Measurements were performed by Mr J. Botes a bio-engineer from a private company called Ergotech, who offer an ergonomics consulting service to industry and are a Department of labour approved inspection authority for physical and chemical hazards including the measurement of whole-body vibration.

Plates 3.1 and 3.2 Calibration of vibration monitoring equipment before attachment to the forklift.



Plates 3.3 and 3.4 Placement of the accelerometer on the seat surface and the chassis for assessment of the SEAT % transmissibility value.

Plate 3.5 Placement of the pre-amplifier unit on the forklift to the radio telemetry system (aerial) as shown in plate 3.6 (below right).

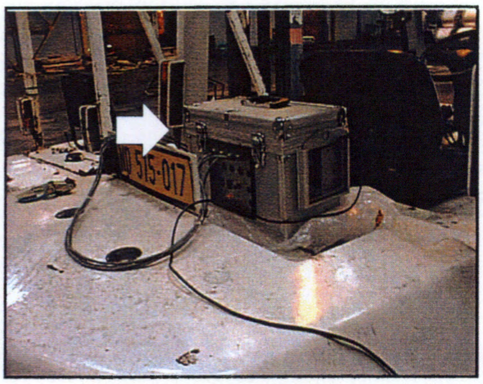


Plate 3.7 Remote personal computer used to capture the radio waves transmitting the vibration data.

All equipment was as per ISO 2631 (1997) and as specified in the South African Bureau of Standards Code of Practice, S.A.B.S- 0259 for accredited laboratories, calibrated on an annual basis. This was done at the National Metrology Laboratory of the Council for Scientific and Industrial research (C.S.I.R) in Pretoria, South Africa. Secondary calibration was carried out on site, before and after each set of measurements were taken. To do this a signal generator was used to send a known electronic signal into the measurement train, and the attenuation of the signal or signal drop was then measured using a Gould calibrator oscilloscope. Appropriate adjustments were then made if necessary to ensure accurate and reliable results. This was carried out at the start and end of each measurement day with results being compared to ensure that no signal changes or inaccuracies had occurred during the measurement period that could give incorrect vibration measurement results.

A full list of the instrumentation used, their serial numbers and calibration dates are provided in appendix I.

3.8.1 The Test Areas and Driving Surfaces

Vibration measurements were conducted over two days in the three areas that were included in the study. In each of these three areas two separate settings were selected to include both smooth (shed) and rough (wharf side) operating conditions to ascertain the effects that driving surface had on the vibration levels. Sheds used for storing break bulk items, ie: not in containers, were chosen as most representative of a smooth operating surface, whilst the area outside the sheds, on the wharf side were chosen as representative of the rough operating conditions, with its poorly maintained often damaged surface crossed by railway lines. Selection of sheds was dictated by logistical considerations related to the volume of work at the port at the time and wether the sheds were not being used for loading and unloading on that day.

Plates 3.8 and 3.9 Test areas (smooth and rough driving surfaces) used in the Point area.

Plates 3.10 and 3.11 Test areas (smooth and rough driving surfaces) used in the Maydon Wharf area.

Plates 3.12 and 3.13 Test areas (smooth and rough driving surfaces) used in the Combi Terminal area.

3.8.2 The Test Vehicles

A total of nine forklifts from the three areas were selected by convenience sampling. Forklifts available in the vehicle pool on the day and at the time of the measurements were obtained by the driver in charge of each area including one vehicle for each type and load capacity of forklift used in those areas. Only vehicles of between 3 to 5 tons (that fell within the study protocol) were included. Portnet also indicated that they would use the data on which forklifts performed the best in the test conditions (had the lowest vibration levels) to decide on future purchases of vehicles.

Table 3.4: Characteristics of the forklifts on which vibration measurements were conducted.

Forklift	Portnet Number or Identity	Manufacturer & Model	Capacity (load)	Driver Weight	Seat is Weight Adjustable?
Point Terminal - G Shed					
A	23 (ND114-847)	Mitsubishi 30 (diesel)	3 000 kg	74 Kg	No
B	172	Mitsubishi 45 (diesel)	4 500 kg	74 Kg	Yes
C	192	Mitsubishi 35 (gas)	3 500 kg	74 Kg	Yes
D	36	TCM FD40 (diesel)	4 000 kg	74 Kg	Yes
Maydon Wharf - Shed 7					
E	ND230-438	TCM FD50 (diesel)	5 000 kg	94 kg	Yes
F	ND126-386	Hyster (diesel)	5 000 kg	94 kg	Yes
Combi Terminal - Shed 101					
G	ND38936	Linde H40 (diesel)	4000kg	85 kg	Yes
H	ND160-995	Mitsubishi PFD510 (diesel)	3 000kg	85 kg	No
I	ND515-017	TCM FD40 (diesel)	4 000kg	85 kg	No

NOTE: all vehicles except the Linde H40 had pneumatic tyres.

:Sample included 8 diesel powered forklifts and one powered by L.P.G gas.

Plates 3.14 - 3.17 Forklifts A, B, C, D evaluated in the Point area.

Plates 3.18 - 3.19 Forklifts E and F evaluated in the Maydon Wharf area.

Plates 3.20 - 3.21 Forklifts G, H and J evaluated in the Combi Terminal area.

3.8.3 The Test Drivers

In each of the three areas one driver was used to drive all forklifts that were to be tested in that particular area, ie: one in Point, one in Maydon Wharf and one in Combi terminal. Each driver was fully briefed as to the aims and objectives of the measurements in Zulu, and were told that they were to drive at a normal speed and manner, as they would have on any normal day, and that four runs per vehicle per surface, and per seat adjustment would be carried out for an average.to be obtained under each test situation. Each driver was also weighed so that the seats that were adjustable could be adjusted for the weight of the driver as per manufacturer instructions (adjusted condition), and then adjusted to the lowest weight and damping (unadjusted) condition. This was in order to ascertain the effectiveness of the seat for vibration damping, and driver protection. Driver's participated in the pilot on the basis of informed consent.

3.8.4 The Measurement Procedure

Thirty-three different exposure conditions were tested as outlined in table 3.5 . The driver did four separate driving runs for each exposure scenario (rough vs smooth), to get an average. This was done firstly with the seat unadjusted to its lowest setting, and then adjusted for his specific weight according to manufacturer specifications. This meant that each forklift, with an adjustable seat, had to be tested over 16 different test runs, to take into account the different variables, ie: rough/unadjusted seat, rough/adjusted seat, smooth/unadjusted seat, and smooth/adjusted seat. Two of the forklifts of the older type, had seats that were not adjustable, and an extra test run was carried out on a loaded forklift to ascertain the effects of loads carried on the vibration levels. Each run took approximately 80-90 seconds. The transfer of the equipment from forklift to forklift took up to 15 minutes per vehicle. Raw vibration data was transferred by the telemetry system via an aerial for capture on a personal computer for analysis later.

Figure 3.4 Position of the accelerometers on the seat and on the chassis of the vehicle for measurement of the SEAT % value.

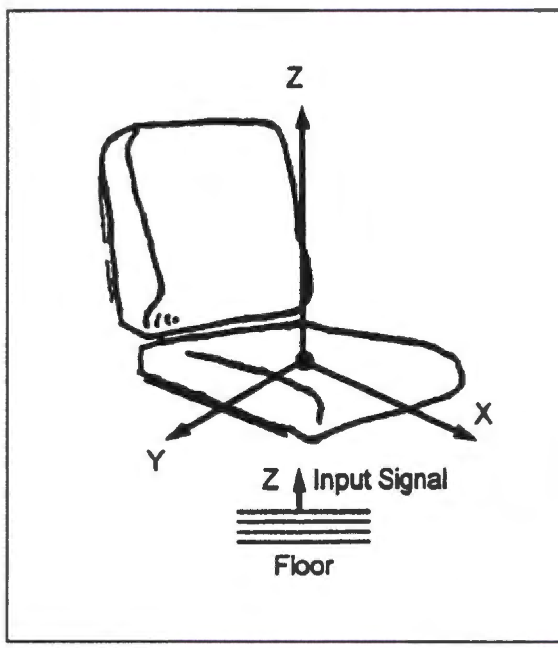


Table 3.5: Measurement conditions and number of test runs per condition.

Forklift	Condition	Test Runs
Point Terminal		
A	Rough Unadjusted	x 4
	Smooth Unadjusted	x 4
B	Rough Unadjusted	x 4
	Rough Adjusted	x 4
	Smooth Adjusted	x 4
	Smooth Unadjusted	x 4
C	Rough Unadjusted	x 4
	Rough Adjusted	x 4
	Smooth Adjusted	x 4
	Smooth Unadjusted	x 4
D	Rough Unadjusted	x 4
	Rough Adjusted	x 4
	Smooth Adjusted	x 4
	Smooth Unadjusted	x 4
Maydon Wharf		
E	Rough Unadjusted	x 4
	Rough Adjusted	x 4
	Smooth Adjusted	x 4
	Smooth Unadjusted	x 4
F	Rough Unadjusted	x 4
	Rough Adjusted	x 4
	Smooth Adjusted	x 4
	Smooth Unadjusted	x 4
Combi Terminal		
G	Rough Unadjusted	x 4
	Rough Adjusted	x 4
	Smooth Adjusted	x 4
	Smooth Unadjusted	x 4
H	Rough Unadjusted	x 4
	Smooth Unadjusted	x 4
J	Rough Unadjusted	x 4
	Rough Adjusted	x 4
	Smooth Adjusted	x 4
	Smooth Unadjusted	x 4
	Rough Adjusted (Loaded)	x 4

3.8.5 Limitations of the Vibration Measurement Results

The results obtained were limited in their application by a number of factors:

Firstly the measurements were not conducted under normal working conditions. The forklifts in all cases except one were unloaded, with no normal work being conducted at the time. It can therefore be concluded that the vibration levels measured would in practice be slightly lower when the forklift is loaded However for the purposes of the pilot study, ranking of activities and exposure scenarios would still be valid.

There was a certain amount of variability in the outside wharf side tarmacadam surfaces. However all drivers, risk officers and berth managers questioned during the survey indicated that the three rough surface areas are not exceptional nor differ much from most areas of the Port and are fairly representative of the general operating conditions.

A limitation is the fact that different drivers were used in each area. However this was unavoidable, as drivers will not and are not allowed to work outside of their designated work area. This may have had an influence due to different driving styles, habits, attitudes or motivations. An attempt was made to control for this by fully briefing the drivers before the tests, and ensuring they understood what was required, ie; not to drive to fast or aim for rough areas and potholes, but to drive as close to normal as possible. The researcher also monitored each test run and gave verbal instructions to the drivers if they were for example driving too fast.

On the two days of the pilot survey, lots of rain was experienced and difficulties arose with protecting the equipment from water, as well as keeping the drivers motivated to drive under those trying conditions. Usually when the rain started indoor measurements were conducted or a break was called until the rain ceased. This also reduced the number of measurements that could be taken. This factor was not considered to pose a confounding problem on the vibration measurements, as the drivers were instructed to drive at normal speeds and as "normal" as possible and this was continually monitored by the researcher to ensure compliance and results that were as close to normal operating conditions as possible.

A more rigorous investigation into whole-body vibration associated with vehicular use would have required a larger randomly selected sample from each area with one driver and multiple conditions. This was not possible and was too costly for this study but may be warranted for future investigations.

3.9 BIAS AND POTENTIAL CONFOUNDING FACTORS

3.9.1 Selection Bias

Brink (1996:104), identifies the biggest threat to internal validity in a quasi-experimental design as selection bias. The compared groups may not have been similar at the beginning of the study. It is therefore important, to test for significant statistical differences in the groups to establish that the groups were as similar as possible in all relevant respects save exposure. This was done for the two groups with respect to important potential factors related to selection bias. (See tables 4.2 - 4.4 in the next chapter.) Selection becomes a problem when differences exist between the two groups, that make it difficult to attribute causality to the specific "intervention" under study.

Another form of selection bias can occur if non-responders in a study are systematically different in their exposure and/or outcome distributions from responders. An attempt to overcome this factor in the study was made by attempting to obtain a 100% response from the study population, thereby including every driver that was available at the times and dates of the questionnaire administration. A total of 20 separate occasions (see table 3.1) were set aside for administration of the questionnaire, so that as many drivers as possible could be included, taking into account the changing weekly shifts, vacation leave, leave for training and courses and drivers away on sick leave. This was all co-ordinated through the drivers in charge of each area, berth managers, and the risk officers from each area. The forklift drivers at Portnet can also be compared to the general population of this particular occupational group, as their working environment, conditions and vehicles are very similar to those found in many other industries.

The following factors were considered as sources of bias:

- Age was considered to ascertain whether or not any one group had significantly more older or younger drivers which could cause a bias in the prevalence rates of lower back pain and other musculo-skeletal disorders as age is a factor in the prevalence rates of lower back pain.

- Exercise, sport and other activities that may have influenced the health status of the drivers, so it was investigated in order to ascertain any significant differences in the groups. Regular exercise would offer a degree of protection against musculo-skeletal injuries, as would other active pastimes.

- Occupations prior to driving were investigated and used to identify and exclude any drivers that had prior vibration exposure from previous employment, so that all effects and outcomes were confined to Portnet and the operational, environmental and exposure conditions.

- Gender was not applicable in this regard as all forklift drivers at Portnet are male.

- Socio-economic status and differences between the areas may be a concern, but the salary scales and access to health and welfare benefits and services of the drivers at Portnet are very similar and may be regarded as homogenous. Grades and scales of pay amongst drivers do not vary across areas and are set in negotiations with management and the unions for all its members.

3.9.2 Confounders

Confounding exists when the variance of one or more independent variables, usually outside the focus of the research, mixes with the variance arising from the independent variables built into the research problem. Consequently, it is unclear wether the relationship found is between the independent and dependent variables in the research design, or between the extraneous independent and dependent variables, or both. Whenever the effects of the independent variables cannot be evaluated confounding is potentially present (Isaac and Michael 1990: 81). So confounding occurs where the confounding factor is associated with both exposure and outcome and changes the exposure-outcome relationship.

Because individuals exposed to the particular agent/intervention (use of back belts) under study may also be exposed to other factors, any association found between exposure/intervention and disease might be mistaken for a causal one, if such confounding is not identified and accounted for either in the design or analysis of the study. According to Leedy (1993:303) a weakness of any experimental design is in the probability that a major event may have entered the system unrecognised along with, before, or after the introduction of the experimental variable. The effects of this factor are likely to be confounded with those of the experimental factor, and the wrong attribution of the cause for the effects observed may be made.

In the Portnet study some important confounding factors were measured and an attempt to control them was made so as to ensure that they did not have an effect on the exposure-outcome relationship. The potential confounders of note were:

1) Age: This was controlled for in the analysis by statistically adjusting for age when doing multivariate analysis;

2) Occupations prior to driving: Drivers who had been drivers prior to working at Portnet and had prior vibration exposure were excluded from this study;

3) Vibration exposure intensities were measured, quantified and compared to check that significant variations did not occur between the areas included in the study;

4) Driving speeds: Opinions of the drivers on driving speeds were used to gather information on how the drivers perceived their driving speed, as this would have a direct influence on the vibration intensities produced when driving speeds are higher. It would have been almost impossible to ascertain exact driving speeds and get the averages in order to compare the driving speeds in the three areas, so the opinions of drivers were obtained to as proxies to ensure that no one group of drivers differed in their driving speed from the other. From the questionnaire responses it was ascertained that drivers in

all the areas were in the opinion that they drove the same speed, no one area had significantly more drivers who said they drove faster or slower than another area. It was also hoped that the question would indicate that not only drivers who drove very slowly or very fast actually presented themselves for the questionnaire administration sessions because of the potential of an increased prevalence of back pain due to increases in whole-body vibration exposure caused by their faster driving speeds.

5) Rest breaks taken during shifts: All the drivers indicated that they had similar shift schedules and systems and they all took breaks at the official mid-shift break period;

6) Other control measures used and effectiveness: No other significant control measures were used in any of the areas that may have had an influence on the outcome variables.

7) The Medical Histories of the drivers from records were originally meant to be used as a tool to ascertain the prevalence of back pain and absenteeism due to back pain, but this data source was discarded due to the inaccuracies in reporting and recording of medical data related to back pain.

8) Shift work: There is a lack of evidence in the literature as to the potential confounding effects of shift work on lower back pain, but the possibility of confounding cannot be disregarded.

9) Self administration of questionnaire: A small minority of drivers completed the questionnaire on their own without the control of the researcher or research assistants. This was due to the fact that some drivers who were fully literate tended to get bored and frustrated going at the slow pace of the other semi or fully illiterate drivers in the groups and were thus given the opportunity to complete the questionnaire at their own pace and ask the researcher any questions or explanation of difficult questions as required. This was seen to be the best practical way of handling this problem at the time. Due to the small numbers of drivers involved this was unlikely to be a major confounder, but needs to be considered nevertheless.

3.9.3 Healthy Worker Effects and Health Based Selection

The healthy worker effect is a phenomenon observed initially in studies of occupational diseases in which workers exhibit lower overall death/morbidity rates than the general population, due to the fact that the severely ill and disabled are ordinarily excluded from employment. Death/morbidity rates in the general population may be inappropriate for comparison if this effect is not taken into account WHO (1986). Bongers and Boshuizen (1990:29), point out that few vibration morbidity studies have addressed this effect, and it is obvious that back trouble has a large impact on health based selection within and from the workforce.

Various factors may be responsible for the healthy worker effect: WHO (1986:139)

1.) Workers generally may be in a better state of health than persons not working or working in occupations with lighter requirements and workloads, for this reason administrative staff are not suitable as a control group as workers.

2.) Many workers drop out from demanding jobs because subjectively and objectively they do not reach a tolerable social and healthy steady state and they thus selectively leave. However, there is evidence at Portnet that staff turnover amongst the drivers is low and most drivers stay in their driving jobs until they retire.

3.) Occupational physicians advise management not to engage persons lacking in the health pre-requisites for a particular job, or they exclude them from such jobs during the course of periodic medical surveillance (active selection). While all employees at Portnet currently undergo a standard pre-employment medical examination, many drivers employed in the 70's and early 80's did not undergo any pre-employment examination as it was then not company policy to do so. The pre-employment medical examination is not specific to driving, except in cases of obvious disability or disease like blindness etc. No routine periodic medical examinations are carried out for employees at Portnet, that would specifically pick up back ailments or damage from whole-body vibration exposure. Thus, there appear to be few factors favouring a healthy worker effect. This is borne out by Portnet risk management who have indicated that no drivers have been moved to other jobs due to back complaints and no drivers have been medically boarded or compensated for back pain or disability.

To minimize the healthy worker effect a working population should be chosen for comparison, (WHO 1986:139). The Portnet study has an internal control group of drivers of a similar demographic, racial, occupational and socio-economic backgrounds which should allow for better controlled comparison of two homogenous groups.

3.9.4 Information Bias

3.9.4.1 Subject Factors

Any changing physical, emotional or psychological state of the subject could introduce error into the measurement (Brink 1996:167). Every respondent was fully informed of the process, aims, objectives and anonymity of the study in their home language, to alleviate any feelings of fear or anxiety or victimisation. All respondents were given the opportunity to ask questions or voice uncertainties or ask for clarification of issues related to the study in an attempt to reduce to a minimum error from subject factors. Other important subject factors that may have an influence on the respondents is the time of day that the questionnaires were administered, with times closer to home time causing workers to rush the questionnaire and not consider their answers carefully. In this regard the questionnaires were not administered after work or at the end of the day/shift, but usually during the mid-shift break or at the start of the shift when it was felt that drivers were relaxed and had time to complete the questionnaire satisfactorily. The varying times of administration were unavoidable due to the logistical problems of organising suitable venues, work loads and driver availability.

Worker expectations regarding the study could have influenced their responses to the questionnaire in two ways. Firstly they may have reported responses that they thought the researcher wanted to hear or alternatively what they thought the study would hopefully find ie: a high prevalence of back pain. This factor was difficult to assess but it is hoped that the thorough briefing of the drivers given before the administration of the questionnaire and the clear statement of the aims and objectives of the research would prevent or limit these influences on the responses.

The respondents could also have been influenced by the presence of the researcher or risk officers, and it was hoped that by allowing the questionnaire administrator to conduct the instruction and questionnaire administration in the home language of the drivers and take the active role, with the researcher and other risk officers in a passive role, that the behaviour of the respondents would not be influenced to any great degree. The questionnaire administrator also has a very good rapport with the drivers and is accepted by them and works with them on a regular basis.

Influences of co-workers on respondents is another factor that can affect the results and it is difficult to ascertain the exact effects without understanding the relationship dynamics within an organisation, amongst the groups and the organisational structures and relationships between workers, thus it is difficult to control this effect. The questionnaire was also not blinded to the specific hypothesis of the study as all drivers were fully informed of the aims and objectives of the study and this may have had an influence on their responses. An attempt was made to avoid this bias by instructing drivers to complete the questionnaire truthfully and to the best of their ability, without consulting each other.

Subject factors could also have influenced whole-body vibration measurements if attitudes and feelings of the drivers towards the problem, their employer and their occupation influenced their driving manner, speed and route. However this was managed by fully briefing the drivers as to the aims and goals of the exercise, and warning against trying to make the vibration levels worse than they would be on a normal day of work. Coupled with this precaution was the fact that during the test runs the researcher continually monitored the drivers doing the test runs and gave instructions accordingly, for example to reduce speeds or take another route when the drivers were seen to be changing their normal driving behaviour. However the drivers needed minimal instruction and correction and completed the tasks satisfactorily.

3.9.4.2 Environmental Factors

Random errors can stem from the physical environment in which the research occurs, such as the weather, lighting, temperature, noise and interruptions. The researcher was unhappy with the first attempts to administer the questionnaire at the work sites on the wharf side, due to the environmental conditions such as rain, heat, dust and noise, as well as the distraction of the drivers by the work in progress. Alternative arrangements were then made to find a more suitable venue and better conditions which were more conducive to this type of activity.

The venues set aside were the mess and ablution facilities, vacant offices and clinic or training facilities or rooms with adequate seating, lighting and in some cases air conditioning. Some of the venues such as the mess and ablution facilities in one area was not completely suitable due to distractions and noise, but no other alternatives could be found so use of the existing available facilities was made.

3.9.4.3 Recall Bias

Recall bias results when respondents systematically report information differentially. It may be deliberate or unconscious especially if responses rely on memory of events in the distant past, or when the respondents do not understand the question due to language difficulties or the complexity of the questions asked. All the responses to certain questions had to be discarded as it was clear that the responses would not offer any valid data due to difficulties in recalling accurate data eg: the question that required the number of days absent due to back pain in the last 12 months elicited responses way below what the medical records indicated in general, and this could probably be attributed to recall bias, and incorrect or under reporting. Recall bias can also be a differential recall based on more intense scrutiny of memory, usually by cases seeking an explanation of a disease or condition such as back pain. Cases thus may have more recall than controls of an exposure.

3.9.4.4 Observer Bias

The researcher and observers can influence the results of the study in many ways, their physical appearance, dress, demeanour and personal attributes can all have an influence on the respondents. With the use of a administered questionnaire, the researcher and assistants did not remain anonymous to the respondents, and researcher affiliation and researcher image may have played a role in the project. Attempts to minimise this was made by having a fully briefed and trained Zulu interpreter administer all of the questionnaires and instructions, with the researcher taking a secondary role by aiding illiterate drivers with the filling in of questionnaires or when large groups were encountered and more help was required.

Inter-observer error was avoided by having only one trained assistant administering the questionnaire process in all three areas. The secondary roles played by the risk officers as research assistants should not have introduced bias or errors as they merely played a passive role in the administrative process and were present at all questionnaire administration session, both with the back belt and control groups . However it must be acknowledged that their presence could have had an unquantifiable effect on the respondents. Intra-observer bias was reduced by training and full briefings given to the questionnaire administrator/interpreter, as to the asking of questions, the avoidance of bias of verbal responses or cues that would influence the response or attitudes of the drivers. The researcher was also always present at every questionnaire administration session to monitor the proceedings. Bias of this nature would not have had an effect on the whole-body vibration results as all measurements were conducted with the same standard equipment, methodology and by the same test officer.

3.9.4.5 Measurement Bias

Many factors causing systematic error stem from poor design of the questionnaire as a measurement instrument. For example unclear questions, unclear directions, the format of the questions, the order in which the questions are asked, and the way the questions are worded may all bias the results. This was addressed in the study by the use of a validated and reliable standardised questionnaire as well as translating the questionnaire into the Zulu language. Pilot testing was done for clarity as well as being reviewed by experts in the field and Portnet employees and union representatives.

3.10 VALIDITY

3.10.1 Validity of the Measurement Instrument

> Leedy (1993: 11) gives a definition of research as "*a studious enquiry or examination, especially a critical and exhaustive investigation or experimentation having for its aims the discovery of new facts and their correct interpretation, the revision of accepted conclusions, theories, or laws in the light of newly discovered facts or the practical application of such conclusions, theories or laws.*"

Validity is concerned with the soundness, the effectiveness of the measuring instrument, or if one is actually measuring what one thinks one is measuring. Leedy (1993:41).

Face validity refers to the researcher's subjective judgement as to firstly the validity of a measuring instrument, actually measuring what it is supposed to measure, and secondly the validity of the sample being measured to adequately represent the behaviour and intervention being tested.

This aspect of the questionnaire was tested during the pilot study phase, when both local and international specialists in the fields of whole-body vibration research, Occupational Health and Safety, Epidemiology and Research Methodology were consulted. [4]

The cross-cultural validity of any questionnaire should not be assumed because it is a standardised questionnaire, as different cultural groups would interpret the questions differently. However with the consultation made when translation of the questionnaire was undertaken by a Zulu speaking person, and then the re-checked by two other Zulu speakers before being back translated into English, it was assumed that the cultural norms and meanings were also translated into the new questionnaire, and any offensive, misinterpreted or misunderstood areas of the questionnaire were identified and rectified. The cultural validity was again tested when union representatives and Zulu speaking Environmental Health students were consulted during the pilot testing phase regarding the suitability of the questionnaire and the questions included, and relevant changes were then made.

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[4] Professor Pat Scott, Department of Human Movement Studies, Rhodes University, South Africa,
Dr Alex Burdorf, Erasmus University, Rotterdam, The Netherlands,
Dr Paul Swuste, Delft University of Technology, The Netherlands,
Dr Paulien Bongers, TNO-NIA, Delft, The Netherlands,
Dr Johan Hendrikse, Ergotech Ergonomics Consultants, South Africa,
Dr Carel Hulshof, Coronel Institute, University of Amsterdam, The Netherlands,
Dr David Standton, National Centre for Occupational Health, South Africa,
Dr Mark Colvin, Medical Research Council, South Africa and
Mr Jacques Oosthuizen, Department of Environmental Health, Natal Technikon, South Africa.

3.11 RELIABILITY

3.11.1 Reliability of the Measurement Instruments

Measures to standardise the questionnaire aimed to ensure reliability of the instrument. These included careful translation of the questions into Zulu, and then back translation to ensure the exact meaning of the questions were not lost. The pilot testing of the questionnaire was also aimed at ensuring the reliability of the questions and certain questions were changed to make sure of this. Only one interviewer administered the questionnaire thereby reducing inter-observer error.

The reliability of the vibration measurements was ensured by using standardised methodology and certified equipment, as well as calibration of the equipment before and after measurements were taken.

3.12 ETHICS

> *"Researchers are trustees of integrity and truth and, as such, need to be scrupulously aware of the ethics of their own conduct."* (Leedy 1993)

Whenever research can have an impact on others, such as humans or animals, the ethical considerations need to be taken into account and addressed, with the ethical propriety according to Leedy (1993:128), lying at the base of these considerations including fairness, honesty, openness of intent, disclosure of methods, the ends for which the research is executed, a respect for the integrity of the individual, the obligation of the researcher to guarantee unequivocally individual privacy, and an informed willingness on the part of the subject to participate voluntarily in the research activity.

No research should ever be conducted under circumstances in which total disclosure of the aims and purposes of the research cannot be set forth, preferably in writing. This issue was addressed in a letter (see appendix C) from the researcher to the Manager: City Terminals, Port of Durban, Mr S.W. Broodryk, in order to obtain consent to conduct the study. In addition meetings were held with the risk management section and relevant union shop stewards. These meetings were conducted in English with interpretation into Zulu and relevant factors concerning the problem to be investigated were outlined in writing (see appendix C) these points were then discussed and questions answered.

Written consent to carry out the study was obtained from Portnet Durban senior management, the Risk Management section, the Human Resource department, as well as relevant union representatives from five different unions across all study areas who had been fully consulted, and informed about the study, it's aims and objectives. Letters were obtained signed by all role-players, that offered co-operation of all concerned to take part in the study. (See appendix C)

This is the first study to be conducted at Portnet concerning ergonomic issues and whole-body vibration exposure of professional drivers. The drivers are a neglected occupational group in many respects will hopefully benefit from this study in that the various ergonomic issues affecting them will be brought to the attention of the management at Portnet for intervention. It will also indicate the presence or absence of evidence regarding the effectiveness of the use of back belts as a protective device against whole-body vibration exposure and wether it is a viable option to be widely implemented, and if not it will indicate the main risk factors, their impact and importance and recommend the control solutions necessary. In this way the quality of the working lives of the drivers will be improved, their health issues addressed, most notably the prevalence and severity of back pain, and their general occupational exposure to whole-body vibration reduced.

Union representatives and drivers indicated their willingness to participate in any study that will improve their working conditions and the health.

3.12.1 Informed Consent

Leedy (1993:130) recommends that a statement signed by the subject, be included in any study indicating a willingness to co-operate in the research and acknowledging that the purpose and procedure of the research project have been explained, and containing a clause that if that if at anytime during the research procedure, the individual should not wish to continue to be associated with the research effort, he or she shall have the right to withdraw without prejudice.

A letter requesting consent was handed to respondents before filling out the questionnaire along with instructions for completing the questionnaire this was then signed and dated by the respondents in the presence of a witness, and all aims and objectives of the study were explained in Zulu or English where applicable, as well as the answering of any questions or concerns. The Consent form with the name of the respondent on front page was then detached in front of the respondent, and placed on a separate pile, separate from the questionnaire which was then completed. This was in order to maintain confidentiality of the respondents at the request of the union representatives.

3.12.2 Ethical acceptability of the measuring instruments

The aim of the research project are explained in the covering letter (see Appendix C), and are clearly discernible from the various items in the questionnaire, in order to render the measuring instrument ethically acceptable. All verbal and written communications were translated into Zulu.

The methods of data collection were non-invasive, and the health data was used in group format only and kept confidential for use by the researcher only. The vibration measurements were conducted on a sample of selected forklifts with three drivers in charge that volunteered to participate in the test driving in each of the three areas.

The study protocol was also approved by the University of Cape Town Postgraduate Programmes Committee, Faculty Board, and the Research and Ethics Committee.

3.13 DATA CAPTURE AND ANALYSIS

3.13.1 Questionnaire Data Capture

The complete questionnaire format was set up on the shareware statistical package distributed by the World Health Organisation, EPI-INFO-6 (available on-line), which is specifically designed to allow for ease of data capture, control, checking and analysis of epidemiological data. The questionnaire was set up in such a way that all data entry field locations in the questionnaire whether text, yes/no or numeric, were designated allowing for capture of the required data from each questionnaire.

A check file was then created for the questionnaire that contained commands that guide, control and refine the data entry process. The commands were set for each data entry field so as to set up constraints for data entry that helped to eliminate errors at the capture stage. The check commands included Range Checking (Min/Max), Legal Values, Must Enter, and Conditional Jumps (Skip Patterns). These commands helped to ensure the data input process was as controlled as possible, and the programmed constraints ensured each entry was verified against the check commands before it was accepted by the computer.

All questionnaires were checked by the researcher for unclear answers or responses that were difficult to decipher due to untidy handwriting or uncertain or incomplete answers, and these were deciphered if possible or marked as left out, to avoid confusion at data input, and avoid incorrect information being entered that may have influenced the results.

Useful variable names were also created to allow the different variables to be identified, and this was done automatically by the EPI-INFO6 programme, that looks for the first ten non-punctuated characters that then become the name. However some of these had to be changed by the researcher to avoid confusion and make the variable names more meaningful. Each one was checked and if necessary new ten character variable names were then created for that data field in order to differentiate between variables with similar or meaningless names.

Each data field on the questionnaire was given a unique code as to the possible responses, eg: yes = 1, no = 2 and not applicable = 3, and this allowed the capture of data to be carefully controlled and meaningful for later analysis.

Coded questionnaire data was then captured by a secretarial administrative assistant, Miss Michelle Bailey, a total of 221 questionnaires before exclusion criteria were applied, and a total of 6000+ different data fields were captured from all the different questionnaire responses collected. The researcher then did spot checks for accuracy on the data capture with randomly selected questionnaires checked question by question.

The data cleaning stage was next where responses that did not make sense were changed or excluded depending on other responses in the questionnaire, eg: if a forklift driver had never worn or been issued with a back belt then he could not make any comment on the comfort, quality or other directly related issues, therefore if comment had been made and the response data captured as such then these were marked as not applicable during the data cleaning process so as to exclude the unsubstantiated opinion of the driver that was not based on the actual experience of wearing the belts. This process was carried out for each variable that had an associated response somewhere else in the questionnaire, and each variable was then checked against the other/s to ensure that the responses were warranted, made sense and were clear and unambiguous. This was however always done so as not to bias the results, by interpretation and reference to the responses in the actual questionnaire under scrutiny. This was carried out using the Read, Browse and update DOS functions and capabilities of EPI-INFO6.

3.13.2 Vibration Data Capture and Frequency Analysis

The raw vibration data electronic signal from the accelerometer was passed through a series of charge amplifiers and sent via the custom built telemetry system and aerial for real time capture on a nearby personal computer. After the measurement the vibration data was imported from the personal computer based logging system into the ERGOTECH custom analysis software package for frequency analysis and evaluation.

The results for all measurement factors and calculated values were presented in tabular form and results were calculated for each test situation averaged over the four individual runs conducted under the different terrain conditions and seat settings.

3.13.3 Questionnaire Analysis

The data consisted of 198 fork lift drivers from three sites. Two sites were in back belt arm: Point (n = 108) and Maydon Wharf (n = 50) and the remaining site in the control arm, Combi Terminal (n = 39). Of the 158 drivers in the back belt arm 13 started work after the start of the project. The intent-to treat principle was applied and all remaining subjects were included in the analysis regardless of their level of compliance. Because compliance may be related to the effectiveness of the belt, it was felt that excluding the non-compliant could bias the results. However sub-analysis were conducted to take account of actual usage amongst the user group. Thus in total 158 drivers were included in the analysis: 108 from Point and 50 from Maydon Wharf. Response rates are discussed in the next chapter (section 4.1.1). Data analysis was conducted using firstly basic univariate and bivariate analyses and then more detailed multivariate statistical modelling.

Basic demographic and driving characteristics were compared among the sites using chi-square tests for categorical data and analysis of variance for numeric variables. The effectiveness of the back belts was assessed by comparing the outcome measures between the back belt groups and the control group. If there was no difference in response amongst the two back belt groups, the combined group was compared to the control. The data on prevalence of back pain was tested first and then severity of back pain was examined. Other variations amongst the back belt users and non-users were investigated by including patterns and degree of usage of back belts.

Categorical variables were compared using chi-square tests. For ordinal variables such as severity of back pain and length of back pain where the assumption of normality could not be made, Wilcoxon rank sum test was used.

A sensitivity analysis was conducted and drivers totally non-compliant were excluded and the data re-analysed to see the effect on the results. The outcome variables were then examined in relation to a proxy measure of vibration intensity since individual driver exposure data were not available. The proxy measure of vibration intensity was calculated by multiplying the predicted vibration level per area by the number of years driving for Portnet (ms^{-2} - years). The intensity had a bimodal distribution and was categorised as low ($\leq = 22$ ms^{-2} - years) and high ($\leq = 23$ ms^{-2} - years). The number 22 was selected as the cutoff between the two categories. The overall median value was 22 ms^{-2}/years with a range of 1.1 to 55.1 ms^{-2} - years. This proxy measure was highly correlated with years driving ($r = 0.92$) and also associated with work area ($p = 0.02$).

Multivariate models were also conducted on the back belt users excluding controls to investigate other potential variations amongst the back belt users and non-users by including patterns and degree of usage of back belts in the model, and to control for confounding by area of work.

A stepwise procedure with backward elimination was used to identify the most parsimonious model, independent risk factors associated with back pain and adjust for confounding. The likelihood ratio chi-square and Hosmer Lemeshow goodness of fit statistics were used to determine the best model. The level of significance used was $p = 0.2$ for entry and $p = 0.3$ for elimination.

A number of different outcome measures were examined: regular back pain (ever), back pain in last 12 months, back pain today and back pain after driving. Outcome measures were further refined to examine lower back pain only. In addition, the duration of pain and the type of back pain (acute or chronic) were also examined. The independent variables included in the model were: work area (Point, Maydon/Wharf /Combi Terminal), group (intervention/control), gardening (yes/no), watching TV (yes/no), speed of driving(fast/slow), frequency of breaks (other/every 4-6 hrs), vibration intensity (high/low), age (continuous), belt usage, frequency of belt use (All the time\ Sometimes \ Rarely or Never) and length of driving. A second set of models replacing group with use of belt (yes/no) were run and then a third set replacing vibration intensity with years of employment/driving ($\leq$ 9 years and $\geq$10 years). The criteria used for inclusion of the variables in the model were if the effects of a particular variable were significant at the bivariate level it was included and if the variable was a known confounder for back pain eg: age.

Chronicity of back pain (chronic versus acute) was analysed by allocating scores to the pain, i.e. if the severity of the pain at its worst scored two or more times greater than the severity at its least, it was classified as variable or acute. If the pain levels were similar i.e. the same or with one score difference at the two points it was classified as constant or chronic.

3.13.4 Vibration Data Analysis

Measurements of multi axis RMS were taken on nine fork lifts: 4 (Point terminal), 2 (Maydon Wharf) and 3 (Combi Terminal). Readings were taken on a rough and smooth surface with adjusted and unadjusted seats for each forklift. Complete data is available on seven forklifts as two forklifts did not have adjustable seats therefore data was collected only for unadjusted seats. Vibration levels were not normally distributed and a log transformation was used and geometric means reported. The association of each factor with vibration levels was examined first and then a linear multivariable model was used to identify which factors independently effected vibration levels. Independent factors included in the model were: type of road condition (rough/smooth); seat adjustment (adjusted/unadjusted); work area(Point/Maydon Wharf/control) and S.E.A.T. %.

Comparison among the areas were made using an analysis of variance to compare the Root-Mean Squared (RMS) mean vibration levels among the three sites under the various test scenarios taking into account driving surfaces and seat adjustments.

NOTE: The fork lifts were not randomly selected but were ones available on the day and thus a sample of convenience. Because of the nature of the sample and the small numbers, the generalisation of the findings is problematic.

3.13.5 Calculation of Proxy Measure of Vibration

As individual driver vibration exposure levels were not available, a proxy measure based on the predicted vibration level from the pilot study of the vibration measurements was calculated for each work area. It was decided that a rough driving surface, with an unadjusted seat and mean % SEAT value for attenuation ability of the forklift seats would be used to derive the prediction equation. These three factors most closely resembled the actual operational conditions at the port in all three areas ie: the forklifts are driven most of the time in the three areas (proxy values: Control Area = 0, Point = 1 and Maydon Wharf = 2) on a rough surface (proxy value = 1), with the seat unadjusted (proxy value = 0). Once the prediction equation had been derived the predicted values for each area were inserted into the calculation and a proxy vibration value calculated that could then be used in the multivariate models.

The proxy measure of vibration intensity was calculated by multiplying the predicted vibration level per area by the number of years driving for Portnet to derive ms^{-2} - years.

Epi-Info, version 6, (Center for Disease Control, Atlanta Georgia) was used for data entry and preliminary analysis. SAS Statistical Software, (SAS Corp. Carey, NC),was then used for more detailed modelling and statistical analysis.

CHAPTER 4:
RESULTS

4.1 Introduction

In this chapter the results of the questionnaire administered to the forklift drivers as well as the vibration pilot study are presented. Results of the different types of analyses are tabulated and presented with some explanation. The results are set out as follows:

1. Study response rates.

2. Univariate statistics stratified by area are presented firstly to describe the sample populations of the three different areas and their characteristics. Demographic data are presented first and important potential confounders as well as occupational an non-occupational risk factors dealt with after that. This is followed by the characterisation of back pain experienced by the drivers such as the prevalence, severity, duration and location of the pain, where after the factors surrounding the use of back belts are covered. Aspects such as compliance with use, and attitudes, opinions and beliefs of the users on the effectiveness, comfort and other relevant aspects of these devices are discussed.

3. Bi-variate comparisons of workers using and not using back belts is then included. For the purpose of these analyses the two groups issued with the back belts (Point and Maydon Wharf) were combined as one group after comparisons on major potential confounders (tables 4.2 - 4.4) found no significant differences. The combined group was compared to the control group (Combi Terminal) and all analysis was conducted in this way. Whole-body vibration is also characterised in this section and operating and exposure conditions and factors are investigated in the analyses. Analyses was conducted for duration of employment as a marker of the duration of whole-body vibration exposure. In this section the relationships between years of service and the back pain characteristics are investigated between the two groups, to characterise and compare factors such as onset of back pain, duration, prevalence etc.

4. Multivariate analyses were then conducted with statistical modelling being used to explore the more complex relationships between the different variables.

In this regard vibration levels were assessed more thoroughly with various independent factors inserted into the model to assess the significance of the associations, and on this basis they were either included or discarded in the final model. Vibration levels were not normally distributed and a log transformation was used and vibration geometric means reported. The association of each factor with vibration levels were examined first and then a linear multivariable model used to identify which factors independently affected vibration levels. Independent variables included in the model were : type of driving surface (rough/smooth); seat adjustment (adjusted/unadjusted); work area (Point/Maydon Wharf/Combi Terminal); and Seat Transmissibility Value (S.E.A.T. %).

Back pain was also investigated further with multivariate logistic modelling to identify and assess independent risk factors associated with back pain such as years of employment, and other occupational and non-occupational risk factors.

4.1.1 Response Rates

Table 4.1: The different response rates from the areas included in the study.

Work Area	Population	Participants	Response Rate
Point	105	105	100 %
Maydon Wharf	55	53	96 %
Combi Terminal	131	51	39 %

The sample sizes varied between the three areas tested with a much larger percentage of the drivers participating from the areas where the back belts were issued ie: Point and Maydon Wharf (This included 100% of drivers in the Point area and 96% of drivers in the Maydon Wharf area.). Because Point and Maydon Wharf were considered to be the intervention group greater effort was made to recruit subjects from these areas and as many as possible were required to complete the questionnaires. The non-participating drivers were either on leave or ill, and missed the questionnaire administration sessions by chance on all the occasions set aside. No data were available on the demography of the non-responders to compare to responders. The response rate from the control group from Combi Terminal was 39% before final exclusion criteria were applied. The Combi Terminal sample was achieved by convenience sampling. Drivers were asked to present themselves at the venue in the mornings of the questionnaire administration and were given time off, which was considered to be an incentive to the drivers. Note that the final response rate was still able to generate sufficient power to detect a 23% change in baseline prevalence from 90% with a $\beta = 0.8$ and $1 - \alpha = 0.05$.

4.2 UNIVARIATE AND BIVARIATE STATISTICS

4.2.1. Demographic Data

Demographic data are summarised in Table 4.2. The mean age was not significantly different among the three work areas: (Point 47.6 (SD 6.8); Maydon Wharf 46.2 (SD 7.7) and Combi Terminal 49.1 (SD 7.2), p = .17). There were no significant differences in race or prior occupation.

Table 4.2: Summary of demographic data.

Data	Back Belt Group			Control Group	P * Values
	Point	Maydon Wharf	Total	Combi Terminal	
	n = 108	n = 50	n = 158	n = 39	
Age (Yrs)	Mean(SD) 47.6 (+/- 6.8)	Mean(SD) 46.2 (+/- 7.7)	Mean(SD) 46.9 (+/- 7.3)	Mean(SD) 49.1 (+/- 7.2)	0.17 [1]
Race:					
Black	102 (94%)	50 (100%)	152 (96%)	38 (97%)	
Coloured	0 (0%)	0 (0%)	0 (0%)	0 (0%)	0.33 [2]
Indian	4 (4%)	0 (0%)	4 (3%)	0 (0%)	
White	2 (2%)	0 (0%)	2 (1%)	1 (3%)	
Occupation Prior to Current Job:					
General Worker	104 (96%)	48 (96%)	152 (96%)	37 (95%)	
Driver	0 (0%)	1 (2%)	1 (1%)	2 (5%)	0.15 [2]
Other	4 (4%)	1 (2%)	5 (3%)	0 (0%)	

* Three groups were compared Point, Maydon Wharf and Combi Terminal
1. ANOVA used to compare means
2.Chi square Fishers Exact was used to compare categorical data.
SD - Standard Deviation

From Table 4.2 it can be concluded that with respect to Age, Race and Occupations prior to driving at Portnet, the two groups of drivers viz: back belt users and control groups are not significantly different. The homogenous characteristics of the different groups allows for easier comparison.

4.2.2 Past Occupational Exposure

Table 4.3: Past occupational driving history.

	Back Belt Group			Control Group	P* Values
	Point	Maydon Wharf	Total	Combi Terminal	
	n = 108	n = 50	n = 158	n = 39	
Total Length of driving forklifts in years	Mean(SD) 14.1 (+/- 8.2)	Mean(SD) 13.9 (+/- 9.5)	Mean(SD) 14.0 (+/- 8.9)	Mean(SD) 12.3 (+/- 10.1)	0.55 [1]
Length of driving at Portnet	14.0 (+/- 8.1)	13.8 (+/- 9.6)	13.9 (+/- 8.9)	12.0 (+/- 10.2)	0.48 [1]

* Three groups were compared Point, Maydon Wharf and Combi Terminal.

1. ANOVA used to compare means

SD - Standard Deviation

Table 4.3 summarises the past occupational exposure of drivers in the three areas. There was no significant difference in either the mean length of driving in years (at Portnet or total length.of driving) amongst the drivers in the three areas.

4.2.3 Potential Confounders - Non Occupational Risk Factors

Table 4.4 summarises sporting and other non occupational risk factors for back pain. The groups appear similar with respect to sport played and dancing. However the two groups are significantly different as regards their level of activity in gardening ($p < 0.001$) and watching television ($p < 0.001$).

Only a small proportion of the drivers in all areas are involved in sporting activities that would possibly offer a degree of protection to the back as it is strengthened by exercise. Other activities also show significant differences ($p = < 0.001$) with many more drivers in Combi terminal taking part in gardening activities which is more of a non-sedentary activity, than drivers in the other two areas, however conversely the drivers in Maydon Wharf and Point have a significantly higher rate ($p < 0.001$) of television watching which is a sedentary activity. This could potentially indicated in part why there are differences in pain prevalence amongst the groups.

Table 4.4: Sporting and other sedentary and non-sedentary activities.

Data	Back Belt Group			Control Group	P *
	Point n = 108	Maydon Wharf n = 50	Total n = 158	Combi Terminal n = 39	Values
Sports and Other Activities:					
Sports: Yes	14 (13%)	5 (10%)	19 (12%)	1 (3%)	0.18 [1]
Gardening: Yes	50 (46%)	20 (40%)	70 (44%)	35 (90%)	p<.001 [1]
Dancing: Yes	5 (5%)	0 (0%)	5 (3%)	2 (5%)	0.28 [1]
Watching TV Yes	52 (48%)	12 (24%)	64 (41%)	7 (18%)	p<.001 [1]

* Three groups were compared Point, Maydon Wharf and Combi Terminal.

1. Chi square Fishers Exact used to compare categorical data .

4.2.4 Potential Occupational Risk Factors

Table 4.5: Risk Factors and Protective Measures amongst Drivers.

Data	Back Belt Groups	Control Group	Total	P
	Total	Combi Terminal		Values
	n = 158	n = 39	n = 197	
Opinions of Driving Speeds:				
Slow	15 (10%)	3 (8%)	18 (9%)	
Average	117 (74%)	27 (69%)	144 (73%)	0.61 [1]
Fast	24 (15%)	9 (23%)	33 (17%)	
Very Fast	2 (1%)	0 (0%)	2 (1%)	
Other Control Methods Used:				
Cushion: Yes	20 (13%)	2 (3%)	22 (11%)	0.25 [1]
Take Regular Breaks and Walk Around:				
Every 4 or 6 hours depending on shift:	137 (87%)	38 (97%)	175 (89%)	0.08 [1]
Take breaks at other times	21 (13%)	1 (3%)	22 (11%)	

1. Chi square Fishers Exact used to compare categorical data .

Drivers opinions about their driving speeds the two groups appear similar across groups with most (72 %) drivers reporting an average driving speed. With respect to other control measures used, such as use of a cushion for back support whilst driving, the two groups were not significantly different, with the majority of drivers (89%) not using extra cushioning on the seat as a control measure. With regards to the rest breaks taken the two groups do not differ significantly, as most drivers (92%) take a break only at the mid shift official lunchbreak time.

4.2.5 Back Pain

In the entire sample 86% of drivers reported previous back pain.

Table 4.6.1: Prevalence of back pain (ever).

Data	Back Belt Groups	Control Group	Total Drivers	Prevalence Ratio for back Pain for Back belts Versus No Back belt (95% CI)
	Total	Combi Terminal		
	n = 158	n = 39	n = 197	
Onset of back pain in years: *	Mean (SD) 9.05 (6.8)	Mean (SD) 9.6 (8.2)	Mean (SD) 9.3 (7.5)	
Prevalence of Back Pain (Pain ever): Yes	145 (92%)	31 (80%)	176 (89%)	1.2 (1.0 -1.4)
Point Prevalence: Back Pain Today: Yes	66 (42%)	19 (49%)	85 (43%)	0.9 (0.6 -1.2)
12 Month Period Prevalence (Pain in last 12 months): Yes	144 (91%)	31 (80%)	175 (89%)	1.2 (1.0 - 1.4)

* p = 0.4 (ANOVA used to compare means)
SD - Standard Deviation

4.2.5.1 Prevalence of Regular Back Pain (ever)

The combined back belt groups reported significantly more back pain than the control - 92 % vs 80 % (PR: 1.2; 95% CI 1.0 - 1.4). The overall prevalence of back pain amongst all the drivers was high with 86% of drivers in all the areas of the study having experienced back pain at some stage in their lives. Sub-analysis showed here were no significant difference in the proportion with back pain between the two back belt areas, Point - 90 % (97/108) and Maydon Wharf - 96% (48/50), (p = 0.16).

4.2.5.2 Point Prevalence (pain today)

There were no significant differences in the point prevalence between the three groups. Although the Prevelance Ratio for belt users was less than 1 (i.e. protective effect) this was not statistically significant. The questions were asked at different times of the day, so may not be an accurate reflection of the point prevalence for a particular day. No data were recorded on times of questionnaire administration. Questionnaire administration times were subject to the availability of drivers and were influenced by the operational requirements and schedules at the port. These results may be somewhat influenced by the fact that in Combi Terminal the questionnaires were administered before the work shifts started so Point prevalence would be expected to be much lower as very little driving had taken place. Thus most of the drivers who usually suffered from and would have reported acute pain immediately after driving a forklift would be excluded in the Combi area.

4.2.5.3 12 Month Prevalence

The combined back belt group showed a significantly higher proportion of reported back pain over the last 12 months, 91 % vs 80% in the control (OR 1.2; 95% CI 1.0 - 1.4) $p = 0.049$. Sub-analysis within areas showed there was no significant difference in the proportion of drivers with back pain over the last 12 months between the Point area and Maydon Wharf, $p = 0.79$.

Table 4.6.2: Location and severity of back pain

Data	Back Belt Group		Control Group		Total Drivers	Prevalence Ratio for Back pain for Back belts Versus No Back belt (95% CI)
	Total		Combi Terminal			
	n = 158 *		n =39 *		n = 197 *	
Location of Back Pain in Sufferers:						
Shoulder Area	18 (11%)		12 (31%)		30 (15%)	0.4 (0.2 - 0.7)
Middle Back	17 (11%)		4 (10%)		21 (11%)	1.1 (0.3-4.6)
Lower Back	131 (83%)		24 (62%)		155 (79%)	1.4 (1.0-1.7)
No Pain	14 (9%)		8 (20%)		22 (11%)	-
Pain Severity of those with Lower Back Pain:	n = 131		n = 24		n = 155 Totals Least	n = 155 Totals Worst
	Least $	Worst #	Least $	Worst #		
Pain Numerical Rating Scale:						
0 - 24	23 (18 %)	0 (0 %)	0 (0 %)	0 (0 %)	23 (15%)	0 (0%)
25 - 49	94 (72 %)	37 (28 %)	18 (75 %)	0 (0 %)	112 (72%)	37 (24%)
50 -74	11 (8 %)	60 (46 %)	6 (25 %)	13 (54 %)	17 (11%)	73 (43%)
75 - 100	3 (2 %)	34 (26 %)	0 (0 %)	11 (46 %)	3 (2%)	45 (29%)
Total	131 (100%)	131 (100%)	24 (100%)	24 (100%)	155	155

* Sums can exceed 100 % due to recording of multiple sites of pain.

Comparison of Pain at Worst - Fishers Exact. P Value for back belts versus no back belts = 0.004

$ Comparison of Pain at Least - Fishers Exact.. P Value for back belts versus no back belts= 0.008

From Table 4.6.2 the following appears:

4.2.5.4 Location of back pain

Workers reporting pain were asked where the pain occurred: shoulder, middle or lower back.

a. The combined back belt groups showed more lower back pain than the control group, 83 % vs 62%, p = 0.04. (OR: 1.4; 95% CI 1.0 - 1.7).

b. Middle back - there was no significant difference in the proportion reporting middle back pain.

c. Shoulder - The combined back belt group showed significantly less shoulder pain than the control group, 11 % vs 31 %, p = 0.001 (OR 0.4; 95% CI: 0.2 - 0.7).

4.2.5.5 Severity of lower back pain

For those experiencing pain, the severity levels of lower back pain at its worst and least were coded 0 1 2 3 (0%, 25%, 50%, 75% and >75%).

There was a significant difference in the pain levels between the intervention and control groups for pain at its least (p = 0.008; Wilcoxon rank sum test) and for pain at its worst (p = 0.004 Wilcoxon rank sum test). The back belt group experienced pain that was less severe than the non belt wearers. Thus although the back belt group experienced more lower back pain (table 4.6.2), the pain at both its worst and least, was reported as less severe than the worst and least back pain reported by the controls (non-wearers).

Table 4.6.3: Duration of back pain after driving.

Data	Back Belt Groups Total n = 145	Control Group Combi Terminal n =31	Total n = 176	P Values
How Long does the Pain Last:				
Several Hours	51 (35%)	17 (57%)	68 (39%)	0.03
Several Days	54 (37%)	8 (27%)	62 (35%)	
Several Weeks	6 (4%)	1 (3%)	7 (4%)	
Several Months	3 (3%)	0 (0%)	3 (2%)	
Always Present	31 (21%)	4 (13%)	34 (20%)	

4.2.5.6 Duration of back pain

In table 4.6.3, amongst those experiencing back pain the back belt groups showed pain of a significantly longer duration with 28% of the drivers having pain lasting more than several weeks to always present, and the controls had pain of a shorter duration with 84% having pain that only lasted hours or several days.

4.2.5.7 Chronicity of Pain

Chronic vs Acute Pain - if the severity of pain at its worst scored 2 or more greater than the severity at its least, it was classified as variable or acute. If the pain levels were similar ie: the same or with one score difference at the two points, it was classified as constant or chronic.

Table 4.6.4: Chronicity of back pain for all drivers in the study (i.e. Point, Maydon Wharf and Combi Terminal).

Data	Total Drivers n = 197
Acute/Variable Pain	56%
Constant/Chronic Pain	44 %

From Table 4.6.4 it appears that when the chronicity of pain of all drivers was compared it showed that the percentage of pain that was reported as constant or chronic by the drivers was lower (44%), than that reported as acute or variable pain (56%).

Table 4.6.5: Chronicity of back pain for the back belt versus the control group.

Data	Acute/Variable Pain	Constant/Chronic Pain	P Values
Back belt Group (n = 158)	56 %	44%	0.85
Control Group (n = 39)	59%	41%	

From Table 4.6.5 it appears that when the chronicity of pain of the two study groups (i.e. Back belt versus Control group) was compared it showed that the percentage of pain that was reported as constant or chronic by both groups of drivers was again lower (44% and 41%), than that reported as acute or variable pain (56% and 59%) . The difference between the two groups was not significant (p = 0.85 Chi-square test).

Table 4.6.6: Chronicity of the back pain as related to the duration of pain.

Data	Acute/Variable Pain	Constant/Chronic Pain
Pain Duration:		
Several Hours	76 %	24 %
Several Days	64 %	36 %
Several Weeks or Months or Longer	43 %	57 %

From Table 4.6.6 it appears that when the duration of pain was compared between the two classifications (Acute/variable and Constant/chronic) it showed that the percentage of pain that was reported as constant or chronic increased as the duration of pain increased, 24 % for pain lasting several hours, 36 % for pain lasting several days and 57 % for pain lasting weeks or longer. For acute or variable pain the opposite was seen with most drivers (76 %) having pain lasting several hours, 64 % for several days and 43 % several weeks or longer. These results are in the direction expected and indicate that the chronicity classification is a valid measure of chronicity for this study.

Table 4.6.7: Back pain after driving and treatment received.

Data	Back Belt Groups	Control Group	Total	Prevalence Ratio Back belts Versus No Back belt (95% CI)
	Total n = 158	Combi Terminal n = 39	n = 197	
Back Pain after Driving:				
Yes	145 (92%)	30 (77%)	175 (89%)	1.2 (1.0 - 1.4)
Lower Back Pain after Driving:				
Yes	131 (83 %)	24 (62 %)	155 (79%)	1.4 (1.0 - 1.7)
Treatment for Back Pain:				
Yes	88 (56%)	23 (59%)	111 (56%)	0.9 (0.7 - 1.3)
Take Medication for Back Pain:				
Yes	61 (39%)	12 (31%)	73 (37%)	1.3 (0.8 - 2.1)
Absence from Work due to Back Pain				
Yes	34 (22%)	6 (15%)	40 (20%)	1.4 (0.6 - 3.1)

Table 4.6.7 suggests that:

4.2.5.8 Pain after Driving

Back pain after driving was reported as significantly more common amongst the back belt group for both back pain and lower back pain. The majority of drivers (99%) that reported back pain also reported pain after driving.

4.2.5.9 Treatment for back pain

1) Their were no significant differences between groups in the provider whom the drivers sought treatment (i.e. traditional healers or doctor), in the use of medication or in the absence from work. Similar results were found for the results of a sub-analysis of only those drivers that reported back pain. However, the back belt group had a non-significant 50% increase both in absenteeism and the use of medication. The majority (36%) in the back belt groups sought treatment from a doctor, and slightly more in the control group (35% versus 22% in the back belt group) sought medical treatment from traditional healers alone. In both groups the numbers did not differ significantly (36% versus 39% in the back belt and control groups for drivers consulting both traditional healers and medical doctors). Overall (29%) reported consulting traditional healers for their back pain.

b. When the proportion taking medication was compared, Maydon Wharf (39%) showed a significantly higher proportion of workers taking medication for back pain when compared to Point (32%), $p = 0.02$ and Combi Terminal (31%), $p = 0.05$.

The seeking of treatment and taking of medication for back pain as well as the absenteeism due to back pain may all be important markers of pain severity, and all the results from table 4.6.7 above seem to show either no significant difference or a small non-significant difference in the direction of the back belt group.

4.2.6 Back Pain (Back belt group)

Risk factors associated with back pain were investigated for all drivers combined and then for only back belt users in order to identify significant risk factors associated with back pain (Ever, in the Last 12 months, and After Driving) for later inclusion in the multivariate models. Results that showed significant differences between the combined group as compared to the back belt group on bivariate analysis are shown below. Note: the variables Driving Slower and Use Cushion were not used in the multivariate modelling due to small cell numbers.

4.2.6.1 General Back Pain in Back Belt Groups

Table 4.7.1: Factors associated with back pain amongst back belt group.

DATA: FACTORS	TOTAL	NUMBER REPORTING BACKPAIN	COMBINED BACK BELT GROUPS PERCENTAGES	P * # VALUES
Age				
30 -39	26	23	89 %	0.71
40 -49	63	59	94 %	
50 – 70	69	63	91 %	
Length of Driving Forklifts.				
0 - 4 Yrs	26	26	100 %	**0.03**
5 - 9 Yrs	31	25	81 %	
10 + Yrs	101	94	93 %	
Length or Driving for Portnet				
0 - 4 Yrs	27	27	100 %	**0.02**
5 - 9 Yrs	30	24	80 %	
10 + Yrs	101	94	93 %	
Take Medication				
YES	97	85	88 %	**0.02**
NO	61	60	98 %	
Take Breaks and Walk				
Around	137	128	93 %	0.07
Every 4 - 6 Hrs	21	17	81 %	
Other Times (more frequent than 4 – 6 hrs)				
Play Sport	19	18	95 %	0.6
YES	153	141	92 %	
NO				
Watching TV	94	90	96 %	**0.03**
YES	64	55	86 %	
NO				
Gardening	88	82	93 %	0.5
YES	70	63	90 %	
NO				
Dancing	5	4	80 %	0.3
YES	153	141	92 %	
NO				
Driving Speed	15	13	87 %	0.6
Slow	117	108	92 %	
Average	26	24	92 %	
Fast/V Fast				
Use Belt	129	121	94 %	**0.007**
YES	15	10	67 %	
NO	14	14	100 %	
Never Given On.				
How often Do you Use a Belt	98	93	95 %	0.4
All the Time	23	21	91 %	
Sometimes	8	7	88 %	
Rarely	29	24	83 %	
N/A				
Use Cushion	20	20	100 %	0.2
YES	138	125	91 %	
NO				
Drive Slower	14	12	86 %	0.4
YES	144	133	92 %	
NO				

* Chi-square and Fishers exact used as appropriate.
# P Values in bold denote p < 0.05

In table 4.7.1 above it can be seen that in this sample Age does not appear to play a significant role in back pain amongst back belt wearers ($p = 0.71$) along with Sport, Gardening, Dancing, and Use of Cushions, Driving Slower, Taking Breaks, Driving Speeds, and Frequency of Belt Use. However, the other factors (Length of Driving, Taking Medication, Watching TV, and the Use of Back Belts) do have a significant relationship to back pain.

There is a lack of a clear dose-response relationship for some of the variables such as Length of driving forklifts both overall and at Portnet and the direction of association remains unclear.

The driving of forklifts and driving for Portnet show a high correlation as most drivers only started driving forklifts after being employed for a number of years at Portnet and never drove before joining Portnet.

The taking of medication can be used as a marker for true back pain experienced by the drivers, as most drivers that did not experience back pain also did not report the taking of medication which is to be expected.

Watching television shows an expected correlation to back pain, possibly as a result of the sedentary nature of the pastime.

The use of back belts shows an association in the expected direction with more drivers that experienced pain making use of the belts in an attempt to alleviate or prevent the back pain.

Although the distribution is significantly different from no difference in distribution, there is no clear dose-effect relationship (Chi-squared tests for trend not significant).

4.2.6.2 Back Pain in Back Belt Users in Last 12 Months

Table 4.7.2: Factors associated with back pain in the last 12 months amongst back belt group.

DATA: FACTORS	TOTAL	NUMBER REPORTING BACK PAIN	COMBINED BACK BELT GROUPS PERCENTAGES	P* # VALUES
Age				
30 - 39	26	23	89%	0.9
40 - 49	63	58	92%	
50 - 70	69	63	91%	
Length of Driving Forklifts				
0 - 4 Yrs	26	24	92%	0.3
5 - 9 Yrs	31	26	84%	
10 + Yrs	101	94	93%	
Length of Driving for Portnet				
0 - 4 Yrs	27	25	93%	0.3
5 - 9 Yrs	30	25	83%	
10 + Yrs	101	94	93%	
Take Medication				
YES	97	85	88%	**0.05**
NO	61	59	97%	
Take Breaks				
Every 4 - 6 Hrs	137	127	93%	0.1
Other Times (more frequent than 4-6 hrs)	21	17	81%	
Play Sport				
YES	19	18	95%	0.5
NO	153	126	82%	
Gardening				
YES	88	80	91%	0.9
NO	70	64	91%	
Dancing				
YES	5	4	80%	0.4
NO	153	140	92%	
Watching TV				
YES	94	88	94%	0.2
NO	64	56	88%	
Drive Slower				
YES	14	13	93%	0.6
NO	144	131	91%	
Use Cushion				
YES	20	20	100%	0.1
NO	138	124	90%	
Driving Speed				
Slow	15	13	87%	0.6
Average	117	107	92%	
Fast/V. Fast	26	24	92%	
Use Belt				
YES	129	122	95%	**0.001**
NO	15	9	60%	
Never Given One	14	13	93%	
How often Do you Use a Belt				
All the Time	98	94	96%	0.4
Sometimes	23	20	87%	
Rarely	8	8	100%	
N/A	29	22	76%	

* Chi-square and Fishers exact used as appropriate.

= P Values in bold denote $p < 0.05$.

In table 4.7.2 above it can be seen that Age again does not appear to play a significant role in the back pain suffered in the previous 12 months by the back belt wearers ($p = 0.9$). Driving for Portnet, Taking Breaks, Playing Sport, Driving Speed Gardening, Dancing, Watching TV, the Use of Cushions, Driving Slower, the Frequency of Belt Use were also not significant in the reporting of 12 month prevalence of back pain. However, the remaining factors (Taking of Medication, and the Use of a Back belt) do have a significant relationship to back pain as discussed above for table 4.7.1.

4.2.6.3 Back Pain in Back Belt Users after Driving.

Table 4.7.3: Factors associated with back pain after driving amongst back belt group.

DATA: FACTORS	TOTAL	NUMBER REPORTING BACK PAIN	COMBINED BACK BELT GROUPS PERCENTAGES	P* # VALUES
Age				
30 - 39	26	23	89%	0.8
40 - 49	63	58	92%	
50 - 70	69	64	93%	
Length of Driving Forklifts				
0 - 4 Yrs	26	26	100%	0.08
5 - 9 Yrs	31	26	84%	
10 +Yrs	101	93	92%	
Length of Driving for Portnet				
0 - 4 Yrs	27	27	100%	0.06
5 - 9 Yrs	30	25	83%	
10 +Yrs	101	93	92%	
Take Medication				
YES	97	85	88%	**0.04**
NO	61	60	98%	
Take Breaks				
Every 4-6 Hrs	137	129	94%	**0.02**
Other Times (more frequent than 4-6 hrs)	21	16	76%	
Watching TV				
YES	94	90	96%	**0.03**
NO	64	55	86%	
Play Sport				
YES	19	18	95%	0.5
NO	153	127	83%	
Gardening				
YES	88	81	92%	0.6
NO	70	64	91%	
Dancing				
YES	5	4	80%	0.4
NO	153	141	92%	
Use Cushion				
YES	20	20	100%	0.2
NO	138	125	91%	
Drive Slower				
YES	14	13	93%	0.7
NO	144	132	92%	
Driving Speed				
Slow	15	13	87%	0.6
Average	117	109	93%	
Fast/V. Fast	26	23	89%	
Use Belt				
YES	129	121	94%	**0.007**
NO	15	10	67%	
Never Given One	14	14	100%	
How often Do you Use a Belt				
All the Time	98	93	95%	0.4
Sometimes	23	21	91%	
Rarely	8	7	88%	
N/A	29	24	83%	

* Chi-square and Fishers exact used as appropriate.

P Values in bold denote $p < 0.05$.

In table 4.7.3 above it can be seen that Age again does not appear to play a significant role in the back pain suffered in the previous 12 months by the back belt wearers ($p = 0.8$). Playing Sports, Gardening, Dancing, the Use of Cushions, Length of Driving Forklifts, Driving Speed, Driving Slower, the Frequency of Belt Use were again not significant in the prevalence of back pain after driving. However the other factors (Taking Medication, Taking Breaks, Watching TV, and Using a Back belt) shown in the table do again have a significant relationship to the development of back pain after driving.

The results show an inconclusive dose response relationship for length of driving with most drivers with 0 - 4 years service having suffered with back pain.

The taking of regular breaks shows a slightly protective effect with fewer of the drivers that took more regular breaks than the officially set times reporting back pain.

From tables 4.7.1 - 4.7.3 it can be seen that the findings are consistent overall across all three tables. Most of the factors found to be significant in the three tables ie: Taking Medication, Taking Breaks, Watching TV, Using a Back belt and Length of Driving showed an overall association with back pain and were thus used in the multivariate modelling.

4.2.7 Use of Back Belts.

Only drivers in the areas provided with back belts were asked about the use and effectiveness of the belts.

Table 4.8: Back belt use and driver opinions on effectiveness

	Back Belt Group		
	Point	Maydon Wharf	Total
	n = 103	n = 46	n = 149
Compliance with use of Back Belt: Yes	97 (94%)	37 (80%)	134 (90%)
Frequency of use of Back Belt:	n = 96	n = 33	n = 129 *
All the time	75 (78%)	23 (70%)	98 (76%)
Sometimes/Occasionally	16 (17%)	7 (21%)	23 (18%)
Rarely/Very Seldom	5 (5%)	3 (1%)	8 (6%)
Opinion of effectiveness of belts in Reducing Pain:	n = 100	n = 34	n = 134
Yes	84 (84%)	24 (71%)	108 (81%)

*Frequency of use not specified n = 5 (Point = 1, Maydon Wharf = 4)

4.2.7.1 Compliance:

a. Issuing of Belts: A small number of drivers were never issued with belts, more so at Maydon Wharf; (n = 8) compared to Point; (n = 6). However these drivers were still included in the analyses on the intent to treat principle. Subsequent analyses were also done using reported usage, which therefore took into account drivers in the back belt area who never used the belts.

b. Use of Belts: Of the drivers issued with belts (n = 149), significantly more drivers used the belts at Point (94%) when compared to Maydon Wharf (80%), p = 0.02. This may be attributed to the fact that the questionnaire administration in Maydon Wharf was carried out at a later stage after Point was completed, and as a result of this time lapse compliance would be expected to drop over time.

c. Frequency of Use: Of the drivers using the belt (n= 129) there was no significant difference in the frequency of use of the belt in the two back belt areas, p = 0.57. A total of 15 drivers in the two areas Point (n = 6), and Maydon Wharf (n = 9) were issued with belts but never wore them.

From table 4.8 it appears that in general, compliance with the use of the back belts was very good, (90% average), and this may be attributed to the fact that the belts were provided and used at the request of the drivers and unions. Frequency of use is also very high, with most of the drivers (76%), wearing the belts all of the time whilst driving. The drivers opinions as to the effectiveness of the belts in reducing lower back pain is also high (81%), and is consistent with the high compliance and frequency of use, as a positive attitude and opinion would increase the use of the devices.

Table 4.9: Attitudes, Beliefs and Opinions of the Users of Back Belts

Question	Answer	Point		Maydon Wharf		Total	
Belts are too hot & uncomfortable	Agree	(24%)	n = 96	(55%)	n = 38	(33%)	n = 134
Belts are too much trouble to wear	Agree	(12%)	n = 97	(53%)	n = 38	(24%)	n = 135
The belt is comfortable	Agree	(18%)	n = 100	(64%)	n = 39	(31%)	n = 139
I do not wear it as it is lost or stolen	Agree	(1%)	n = 94	(0%)	n = 37	(1%)	n = 131
The belt fits me well	Agree	(89%)	n = 98	(69%)	n = 39	(83%)	n = 137
I do not use it as it is broken	Agree	(20%)	n = 92	(22%)	n = 37	(20%)	n = 129
The forklift seat needs to be changed	Agree	(87%)	n = 99	(90%)	n = 39	(88%)	n = 138
I do not know how to wear the belt	Agree	(8%)	n = 95	(13%)	n = 38	(10%)	n = 133
The belt has made my back muscles stronger	Agree	(69%)	n = 98	(62%)	n = 37	(67%)	n = 135
I would rather use something else to prevent back pain	Agree	(18%)	n = 97	(32%)	n = 37	(22%)	n = 134
The belt weakens my muscles	Agree	(12%)	n = 97	(8%)	n = 36	(11%)	n = 133
The belt makes the back pain worse	Agree	(5%)	n = 97	(8%)	n = 37	(6%)	n = 134

4.2.7.2 Attitudes, Beliefs and Opinions

Amongst the users of the back belts various attitudes, beliefs and opinions were measured regarding the use of the back belts and the drivers perceptions towards the devices and the whole-body vibration issues at large.

With regards to the comfort of the back belts only a small minority of drivers felt that the back belts were uncomfortable or hot to wear, yet 24 % also felt the back belts were too much trouble to wear, which corresponded fairly well with the number of drivers (22%) who felt they would rather use something else to prevent back pain i.e. the drivers who found the belts uncomfortable favoured other vibration/back pain control measures. These other measures were unspecified. The vast majority of drivers felt the back belts fitted them well and a surprising high 10% of the drivers felt they did not know how to wear the back belt properly. These devices are usually assumed in industry to be of a very simple design requiring no training for use. A large majority of the drivers felt that the forklift itself needed to be changed or modified in some way to reduce vibration and/or lower back pain. Most of the drivers (67%) thought that the back belt actually strengthened the back muscles perhaps indicative of a "macho culture" set of beliefs amongst the drivers, and only a few (11%) felt that the back belt made the back muscles weaker. A low 6% felt that the back belt actually aggravated the pain and made it worse.

4.3 Whole-body Vibration Data

4.3.1 Introduction

Four mean RMS values were measured for each combination of the different operational conditions; Rough driving terrain + Seat adjusted for driver weight (Rough Adjusted); Smooth driving terrain + Seat adjusted for drivers weight (Smooth Adjusted); Rough driving terrain + Seat not adjusted for driver weight (Rough Unadjusted); and Smooth driving terrain + Seat not adjusted for driver weight (Smooth Unadjusted). Seat adjusted readings for two forklifts, (one at Point and one at Combi Terminal) could not be taken due to seat type. Tables 5.1 to 5.8 shows the summary of the vibration results obtained from the forklifts in the three test areas, along with the test conditions (driving surface and seat adjustment.)

The vibration results from the three groups of forklifts tested (from Point, Maydon Wharf and Combi Terminal) were combined as one group after comparisons for differences between them were made, and this combined group was then compared to the overall EEC Machinery Directive exposure standard of 0.5 ms^{-2}.

The data from the questionnaire responses were combined with the whole-body vibration measurements to estimate whole-body vibration exposure and this metric was included in the detailed multivariate analysis.

4.3.2 Profile of vibration measurements

Table 5.1: Vibration RMS values for combined driving surface and combined seat adjustment results for individual test areas

TEST CONDITION		WORK AREA	VIBRATION RMS VALUES (ms^{-2})			
SURFACE	SEAT		MEAN	SD	MIN	MAX
Rough	Adjusted	Point	1.47	0.39	1.18	1.91
		Maydon Wharf	1.42	0.13	1.33	1.51
		Combi Terminal	0.80	0.03	0.78	0.82
	Unadjusted	Point	2.07	1.03	1.17	3.05
		Maydon Wharf	1.45	0.13	1.36	1.54
		Combi Terminal	1.05	0.31	0.74	1.36
Smooth	Adjusted	Point	1.11	0.32	0.82	1.45
		Maydon Wharf	0.60	0.19	0.48	0.75
		Combi Terminal	0.61	0.04	0.58	0.64
	Unadjusted	Point	1.32	0.60	0.82	2.04
		Maydon Wharf	0.72	0.35	0.47	0.97
		Combi Terminal	0.72	0.14	0.57	0.84

Driving surfaces as well as the adjustment of seats for optimum vibration attenuation are two aspects of the vehicle factors and driving environment that play a large role in the vibration exposure of the driver. In table 5.1 above vibration RMS data are presented stratified by driving surfaces of the various test areas (rough or smooth), seat adjustments and the different work areas.

Table 5.2: Vibration RMS values by driving surface

TEST CONDITION	VIBRATION RMS VALUES (ms^{-2})	
	MEAN	SD
Rough Driving Surface	1.4	0.63
Smooth Driving Surface	0.92	0.43

The effects of the driving surfaces alone on the mean RMS vibration values are shown in table 5.2 above which combines work areas and seat adjustments. For each work area (table 5.1) rough driving surfaces in each test area were higher than the corresponding smooth driving surfaces. Smooth driving surfaces (RMS = 0.92 ms^{-2}; SD: 0.43) when compared to rough conditions; RMS = 1.4 ms^{-2} ;SD: 0.63) had lower mean RMS values as would be expected. (P = 0.01)

Table 5.3: Vibration RMS values by combined seat adjustment for individual test areas

TEST CONDITION	VIBRATION RMS VALUES (ms^{-2})	
	MEAN	SD
Seat Adjusted	1.0	0.32
Seat Unadjusted	1.2	0.54

Although Mean vibration RMS values were slightly higher in unadjusted seats than in the adjusted seats the difference was not statistically significant (p = 0.2). The difference in the direction was as expected.

Table 5.4: Vibration RMS values for combined driving surface and combined seat adjustment results for combined back belt group (Point and Maydon Wharf) and control group (Combi terminal).

TEST CONDITION		WORK AREA	VIBRATION RMS VALUES (ms^{-2})		
SURFACE	SEAT		MEAN	MIN	MAX
Rough	Adjusted	Back Belt Group	1.45	1.26	1.71
		Combi Terminal	0.80	0.78	0.82
	Unadjusted	Back Belt Group	1.76	1.27	2.29
		Combi Terminal	1.05	0.74	1.36
Smooth	Adjusted	Back Belt Group	0.86	0.65	1.01
		Combi Terminal	0.61	0.58	0.64
	Unadjusted	Back Belt Group	1.02	0.65	1.50
		Combi Terminal	0.72	0.57	0.84

In table 5.4 above vibration RMS data for the two groups ie: back belt wearers and control group are presented stratified by the driving surfaces of the various test areas (rough or smooth) and by seat adjustments.

Correct seat adjustment plays an important role in the reduction or attenuation of vibration exposure. It can be seen from the table that when similar driving surfaces are compared i.e. rough to rough or smooth to smooth, the vibration RMS mean values were reduced in all cases when the seats were adjusted correctly. The smooth driving surfaces when compared to the rough surfaces had lower mean RMS values as would be expected.

Table 5.5: Vibration RMS values by driving surface for combined back belt (Point and Maydon Wharf) group and control group (Combi terminal).

TEST CONDITION	WORK AREA	VIBRATION RMS VALUES (ms^{-2})			
		MEAN	SD	MIN	MAX
Rough Driving Surface	Back Belt Group	1.68	0.67	1.25	2.30
	Combi Terminal	0.95	0.26	0.74	1.36
Smooth Driving Surface	Back Belt Group	1.03	0.48	0.65	1.50
	Combi Terminal	0.67	0.11	0.57	0.84

The back belt group have significantly higher mean vibration RMS values when compared to the Combi Terminal group on both rough driving surfaces ($p = 0.04$) and smooth surfaces ($p = 0.04$).

Table 5.6: Vibration RMS values by seat adjustments for combined back belt groups (Point and Maydon Wharf) and control group (Combi terminal).

TEST CONDITION	WORK AREA	VIBRATION RMS VALUES (ms $^{-2}$)			
		MEAN	SD	MIN	MAX
Seat Adjusted	Back Belt Group	1.18	0.42	0.65	1.71
	Combi Terminal	0.71	0.11	0.58	0.82
Seat Unadjusted	Back Belt Group	1.49	0.80	0.65	2.30
	Combi Terminal	0.89	0.28	0.57	1.36

The back belt group also had higher vibration RMS values for both the adjusted ($p = 0.05$) and the unadjusted ($p = 0.10$) seats.

NOTE: None of the average vibration RMS values recorded in the tables above are **below** the EEC machinery directive standard of 0.5 ms $^{-2.}$ Moreover the lowest recorded RMS value was 0.47 ms $^{-2}$ for smooth unadjusted at Maydon Wharf and none of the other conditions gave less than 0.5 ms $^{-2}$. This indicates that almost all drivers in all areas whether they adjust the vehicle seats before driving are over-exposed to whole-body vibration and at a presumed increased risk of developing musculo-skeletal injuries and conditions due to this exposure.

Table 5.7: Average Seat Effective Amplitude Values for the vehicles tested in the different work areas.

TEST CONDITION	WORK AREA	Average SEAT % *	SD
Seat Adjusted	Point	114	29.6
	Maydon Wharf	146	32.8
	Combi Terminal	90	53.7
Seat Unadjusted	Point	102	31.4
	Maydon Wharf	138	68.8
	Combi Terminal	103	37.3

* SEAT values < 100 indicate attenuation of vibration.
SEAT values > 100 indicate amplification of vibration.
SD - Standard Deviation

The seat effective amplitude value (SEAT %) indicates the effectiveness of a vehicles seat (in %) in attenuating or reducing vibration transmission to and exposure of the driver. Any value over 100% indicates vibration amplification and values under 100% an attenuation of vibration. There was no significant difference in the average SEAT values between the adjusted (110.4, SD: 43.9) and unadjusted (121.6, SD: 42.1) seats ($p = 0.6$).

From table 5.7 above it can be seen that the in the Point and Maydon Wharf areas the SEAT % values are over 100% indicating that the forklift seats when adjusted or unadjusted still actually amplify the vibration and do not thus reduce exposure as they should. In the Combi Terminal area the seats do in fact offer some protection and reduction or attenuation of vibration when adjusted correctly. However the values showing the unadjusted SEAT % values are closest to the actual operating conditions at Portnet as drivers do not adjust seats before driving.

Table 5.8 Average Seat Effective Amplitude Values for the vehicles tested with seats unadjusted for driver weight in the two combined back belt groups and the control group.

TEST CONDITION	WORK AREA	Average SEAT % *	SD
Seats Unadjusted	Back Belt Group	114	47.2
	Combi Terminal	103	37.3

* SEAT values < 100 indicate attenuation of vibration.
SEAT values > 100 indicate amplification of vibration.

Table 5.8 shows the control group has better attenuation values than the combined back belt wearing groups. This could explain the lower vibration levels experienced in the Combi Terminal area. However this difference was not statistically significant ($p = 0.6$). This value could also be taken as a proxy for the condition of the vehicle seats with high SEAT % values indicating poorer seats on average in the back belt group. However the Control group had one very new forklift (forklift G in Appendix J) included in the sample that had sophisticated vibration control technologies. This outlier may have influenced the average results as vibration attenuation was very good in this forklift.

In summary vibration levels appear to differ significantly between the Intervention and Control groups. Maydon Wharf in particular had high vibration levels. Vibration levels also differed by road surface but not significant by seat adjustment.

4.3.3 Linear modelling of vibration levels

In order to determine if the differences in measured vibration RMS values between the intervention and control groups could be explained by other factors, a multivariate model was used.(See multivariate modelling.)

Because vibration levels were not normally distributed, a log transformation of RMS levels was used and geometric means of the vibration levels reported. Independent variables included in the model were: type of road condition (rough/smooth); seat adjustment (adjusted/unadjusted); work area (Point/Maydon Wharf/Combi) and S.E.A.T % vibration attenuation. All variables were included using forced modelling.

In the multiple linear regression model, work area was still a significant predictor after controlling for the effect of the other factors. The model was significant, ($p < 0.001$) and explained 61% of the variance in vibration levels (model $R^2 = 61\%$). After controlling for other factors, Point area still differed significantly from the control ($p < 0.001$) and Maydon Wharf ($p = 0.01$). There was no difference between Maydon Wharf and Combi Terminal ($p = 0.4$). An examination of the studentized residuals did not detect any obvious departure from the assumption of normality.

Table 5.9: Model fitting: Log of vibration levels for three work areas.

Variables		Parameter Estimate	Std Error	P value	Partial R^2
Intercept		- 0.60	0.20		
Work area	Point	0.56	0.20	< 0.001	0.41
	Maydon	0.13	0.13	0.4	
	Combi Terminal				
Seat Adjustment	Adjusted	- 0.17	0.11	0.2	0.08
	Unadjusted				
Driving Surface	Rough	0.49	0.11	0.002	0.40
	Smooth				
% SEAT		0.002	0.001	0.24	0.03

1. Vibration levels differed significantly between the Point and Combi Terminal and Maydon Wharf and Combi Terminal groups when the model fitting log of vibration levels was used, and driving surface also differed significantly in the expected direction with vibration levels on rough driving surfaces being significantly higher than vibration levels on a smoother surface. Seat adjustment was not a significant predictor of vibration levels.

2. Because the main analysis grouped Maydon Wharf and Point as the intervention group, the analysis was redone comparing just the intervention and control groups.

Table 5.10: Shows Model fitting: Log of vibration levels for control and intervention groups.

Variables		Parameter Estimate	Std Error	P value	Partial R^2
Intercept		0			
Work area	Intervention	0.44	0.20	< 0.001	0.41
	Control				
Seat Adjustment	Adjusted	- 0.18	0.13	0.17	0.08
	Unadjusted				
Driving Surface	Rough	0.47	0.13	0.001	0.40
	Smooth				
% SEAT		0.002	0.001	0.83	0.03

The model based on combining the two back belt areas as an intervention group showed similar results with the three areas separate. Because vibration levels are known risk factors for back pain and were found to differ between the two groups even after controlling for surface type and seat adjustments, models that investigate predictors of back pain should therefore include vibration level as an independent variable.

The predicted vibration levels for each area were calculated from the results of the regression equation using the variables most typical of actual operational conditions i.e. forklifts driven on a rough surface with the seats unadjusted for weight.

This was carried out for Point and Maydon Wharf, as per the example (Point) shown below:

Point:

Log (predicted vibration levels in m/s^{-2}) = -0.60 + 0.56 (point area) + 0.49 (rough surface) + 0.0 (unadjusted seat) + 0.002 * 97.8 (SEAT % value).

= 0.6456

Predicted Vibration Value = Antilog (0.6456)

= 1.9 m/s^{-2}.

Maydon Wharf: Predicted Vibration Value = 1.3 m/s^{-2}.

Combi Terminal (Control): Predicted Vibration Value = 1.1 m/s^{-2}.

Table 5.11: Log predicting vibration levels in ms^{-2} for the three test areas.

	Back Belt Group		Control Group
	Point	Maydon Wharf	Combi Terminal
Root Mean Square (RMS) Predicted Vibration Levels (ms^{-2}).	1.9	1.3	1.1

Using the linear regression results, a proxy variable for vibration intensity was calculated by multiplying the predicted vibration level per area by the number of years driving for Portnet (Predicted lifetime exposure).

4.4 Stratified Bivariate Analyses

Years of service was selected for bivariate stratified analysis given the expected association of years of service with back pain. Age was considered as a potential confounder in the relationship between years of service and the prevalence of back pain. However, age was not found to be a significant risk factor for back pain (General back pain; p = 0.71, Back pain in the last 12 months; p = 0.9, or Pain after driving; p = 0.8. See tables 4.7.1 to 4.7.3). It was, however, still included in the multivariate modelling.

Table 6.1 : Percentage of drivers with back pain in the past (Ever Back Pain).

Data	Back Belt Groups	Control Group	P Values
	Total	Combi Terminal	
	n = 145 *	n =31 *	
Years of service at Portnet:			
0 - 4	27 (100 %)	12 (75%)	0.01
5 - 9	24 (80 %)	5 (100%)	0.56
10 +	94 (93 %)	14 (78%)	0.06

*Missing data on onset of back pain. (n = 13; n = 8).

From table 6.1 it can be seen that there is a lack of a clear dose response relationship, if years of service is taken as a proxy for exposure and dose. Amongst the back belt group, the highest prevalence is reported for those with either less than 5 years or more than 9 years of service, while the converse is true for the controls, where those with 5 to 9 years of service have the highest prevalence. However, for the controls, these percentages are based on relatively small numbers.

Similar patterns in the dose-response effect were found with regards to the prevalence of back pain experienced by drivers within the last 12 months before the questionnaire administration. (data not presented here).

Table 6.2: Percentage of drivers with back pain on the questionnaire administration day (Point Prevalence).

Data	Back Belt Groups	Control Group	P# Values
	Total	Combi Terminal	
	n = 66	n = 19	
Years of service at Portnet:			
0 - 4	15 (23 %)	5 (26%)	0.22
5 - 9	8 (12 %)	2 (11%)	0.06
10 +	43 (65 %)	12 (63%)	0.10

Chi-square test.

From table 6.2, it can be seen that in the back belt group as well as the control group the lowest point prevalence of back pain is in the middle length of service groups. Under reporting may have occurred with the timing of questionnaires before work shifts, but this would not have occurred differentially across workers by years of service, so this factor cannot explain the dose-response effect. Nonetheless, these proportions are based on small numbers and trends and should be treated with circumspection.

Table 6.3: The relationship between years of service and back pain.

Data	Back Belt Groups	Control Group	Prevalence Ratio Back belts Versus No Back belt (95% CI)
	Total	Combi Terminal	
	n = 57	n = 21	
Prevalence of back pain amongst drivers with 0-9 years service.	51 (89 %)	17 (81%)	1.1 (0.9 - 1.4)
	n = 101	n = 18	
Prevalence of back pain amongst drivers with 10+ years of service.	94 (93 %)	14 (78 %)	1.2 (0.9 - 1.5)

From table 6.3 we can see that with drivers that have less than 9 years of service the back belt group have an insignificant but slightly higher risk of having back pain when compared to the control group (PR: 2.0; 95% CI 0.5 - 7.9).

When considering the drivers with 10 + years of service the risk amongst the back belt group is increased and is again statistically insignificant (PR: 1.2; 95% CI 0.9 - 1.5). When we compare the prevalence ratios of the 0 -9 years service groups and the 10 + groups we can see that the prevelence of pain increase slightly as the years of service increase with an increase in exposure doses. However, the small difference in prevalence ratios suggests that length of service is is not an effect modifier. A Breslow-Day test for homogeneity of the Prevalence Ratios yielded a Prob. = < 0.05 which also indicates that the differences are not significant, and that there is no significant interaction between years of service and back pain status. The vertical Odds Ratios showed that the odds of developing back pain with increasing years of service did not increase in either group i.e. Back belt group (OR 1.6; 0.4 - 5.6) and Control Group (OR: 0.8; 0.1 - 5.0).

Overall when the relationship between the proxy vibration intensity and lower back pain was examined alone not considering other variables, no association was found with lower back pain prevalence (OR: 1.0 95% CI: 0.5 – 2.0, p = 0.9), pain in last 12 months (OR: 1.1; 95% CI: 0.6 – 2.2, p = 0.9), pain after driving (OR: 0.9; 95% CI: 0.5 – 1.9), pain today (OR: 0.9; 95% CI: 0.5 –1.5, p =0.6) or pain at its worst (OR 0.9, 95% CI: 0.5 – 1.7).

4.5 Multivariate Logistic Modelling

Multivariate logistic modelling was used to identify significant predictors of various back pain outcomes with particular attention to the impact of back belts on back pain. Outcomes evaluated included back pain ever, back pain today, back pain in last 12 months and back pain after driving. The full model for all outcomes were significant, except for the outcome back pain today (p = 0.9). Data are presented in this section for the models in which back pain after driving was the outcome. Back pain after driving was deemed to allowed a closer association with the driving occupation than the other outcomes and was thus selected as the main outcome to be presented. The models using other back pain outcomes were broadly similar in the predictors found to be significant and in the direction and strength of associations. Because the inferences were broadly similar not all these analyses are presented here. Likelihood ratio chi square p = 0.0002 and Hosmer-Lemeshow goodness-of-fit statistic suggested good model fit (p = 0.46). Models were also run on the back belt groups alone (i.e. excluding Combi Terminal) which included variables related to back belt usage and compliance rates. This was done to control for the potential confounding effect of higher whole-body vibration levels in the back belt (Point and Maydon Wharf) areas.

Models 1 (All Drivers) and 2 (Back Belt Users) : Independent Variables entered in models:

1. Work Area (substituted Belt Compliance in model 2)
2. Rest Breaks
3. Watching Television
4. Vibration Intensity
5. Age
6. Gardening
7. Driving Speed
8. Length of Driving .

Models 3 (Back Belt Users) and 4 (Back Belt Users) : Independent Variables entered in models:

1. Belt Compliance (substituted Frequency of Back Belt Usage in Model 4)
2. Rest Breaks
3. Watching Television
4. Years Driving
5. Gardening
6. Driving Speeds
7. Length of Driving.

The other equivalent models with back belt use included vibration levels substituted for work area, and pain after driving and duration of pain respectively in place of back pain. These models did not produce a better model as judged from the Likelihood Ratio Chi Square.

Sub-analysis was also attempted on drivers recently employed < 1 year employment (these were drivers excluded from main analysis), to ascertain the presence of any potential healthy worker effects, but this was discarded due to the small numbers involved, n = 23 in the intervention group, and n = 9 in the control group making it unsuitable for analysis.

Table 7.1: Model fitting: Predictors of Back Pain after driving amongst forklift drivers in the three areas. (Model 1. n = 175)

Variables *		OR (95% CI)
Constant		
Work Area	Point vs Combi Terminal	3.4 (CI: 1.3 - 8.6)
	Maydon Wharf vs Combi Terminal	7.9 (CI: 2.2 – 28.2)
Breaks	Other more Frequent Breaks vs Every 4 - 6 hrs	0.2 (CI: 0.07 – 0.6)
Watching TV	Yes vs No	0.6 (CI: 0.2 – 1.3)
Vibration Intensity # (vibration dose)	High vs Low	1.1 (CI: 0.47 – 2.7)
Age		0.97 (CI: 0.9 – 1.0)

* Independent Variables entered in model: Work area, Gardening, Watching TV, Speed of driving, Frequency of breaks, Vibration intensity, Age, and Length of driving.

Proxy of exposure dose (length of service multiplied by proxy vibration value for each area). High = ≥23 and Low ≤22.

Table 7.1 shows the results of the model fitting back pain after driving. The modelling shows that subjects in areas using back belts were significantly more likely to report pain after driving than those in the control group i.e Combi Terminal. These odds ratios were high (OR: 3.4; 95% CI 1.3 - 8.6) for Point and higher (OR: 7.9; 95% CI 2.2 - 28.2) for Maydon Wharf.

1. From the table we can however see that with regards to work area the two back belt wearing groups in Point and Maydon Wharf, risks were not equivalent as the odds of developing back pain after driving was higher in the Maydon Wharf area. The difference in risk cannot be explained adequately by the differences in vibration exposure intensities (RMS values) between Point and Maydon Wharf, as on average the vibration mean RMS values were higher in the Point area when compared to Maydon Wharf. In any event, the vibration intensity variable took account of area differences in RMS whole-body vibration levels, and should have therefore controlled for this variable. However when we take into consideration the average seat effective amplitude values (SEAT %) which can be used as a proxy for measuring the effectiveness of the seat in attenuating vibration and reducing exposure, and in turn the condition of the seats and equipment it is possible that Maydon Wharf has a higher amplification of vibration when compared to Point, which may explain partly the increased odds ratio.

2. With regards to rest breaks taken by drivers during their work shift, most drivers only took their breaks at the official times half way through the shift (either after 4 hours or 6 depending on the shift). However some drivers took more regular rest breaks i.e. more often then the

official breaks, and this could explain the reason why the odds of developing pain after driving is lower amongst these drivers, as their daily vibration exposure dose would be reduced and the time for repair and recuperation of the back and musculo-skeletal organs would be increased thereby reducing the pain duration and intensity. Drivers that only took their rest breaks at the scheduled official times tended to have a higher odds of developing pain after driving.

3. The watching of television would be considered to be a sedentary activity and would be expected to be a risk factor for back pain as less time for exercise is set aside. However, the model shows that in fact this activity would reduce the odds of pain after driving if you are a television watcher. This may reflect confounding effects of the socio-economic gradient, since workers owning a television may be better off than those without.

A second model was run (results presented in table 7.2 below) and included only users of the back belts. Back belts, frequency of reported use were substituted for work area. Likelihood ratio Chi-square, p = 0.005 and Hosmer-Lemeshow goodness-of-fit statistic suggested good model fit (p = 0.85)

Table 7.2: Model fitting: Predictors of Pain after driving amongst back belt wearers (i.e. excluding Combi Terminal). (Model 2. n = 149)

Variables *		OR (95% CI)
Constant		
Frequency of Use	All the time vs Never	2.3 (CI: 0.8 – 7.4)
	Sometimes/Rarely vs Never	4.0 (CI: 1.6 – 9.7)
Breaks	Other more Frequent Breaks vs 4 - 6 hrs	0.2 (CI: 0.06 – 0.6)
Watching TV	Yes vs No	0.5 (CI: 0.2 – 1.1)
Vibration Intensity # (vibration dose)	High vs Low	1.2 (CI: 0.5 - 2.8)
Age		0.96 (CI: 0.9 – 1.0)

* Independent Variables entered in model: Frequency of Use, Gardening, Watching TV, Driving Speeds, Frequency of breaks, Vibration intensity, Age and Length of Driving.

Proxy of exposure dose (length of service multiplied by proxy vibration value for each area). High = ≥23 and Low ≤22.

From the table we can see that with regards to back belt compliance the drivers who wore the back belts all of the time had a higher risk of back pain after driving (OR: 2.3; 95% CI 0.8 - 7.4) than drivers that never wore the back belts. Drivers who wore back belts sometimes also had an increased risk of back pain after driving (OR: 4.0; 95% CI 1.6 - 9.7) compared to drivers that never used back belts. However the dose-response effect was inconsistent in this group, with the highest risk in drivers using the back belts sometimes. This could suggest a protective effect of the back belt on belt wearers who reported good compliance relative to "sometimes". However, both user groups had increased risks of back pain after driving . Good compliers may simply be drivers who complied with other safety precautions such as adjustment of the seat before driving, reduced driving speeds or taking regular breaks. Relative to non-users, belt users are still worse off, irrespective of how frequently they use the belts.

The association may also not be causal and interpretations should be made with care. Back belt wearers may have tended to wear the belt less if they had less pain and more if they had more pain. Therefore the drivers with little or no pain may not have bothered to wear back belts very often or at all, whereas the drivers with the worst pain may have worn the back belts all or most of the time.

Table 7.3: Model fitting: Predictors of Pain after driving amongst back belt user groups (excludes Combi Terminal) and compliance with back belt use. (Model 3. n = 158)

Variables *		OR (95% CI)
Constant		
Belt Compliance	Yes vs No	11.6 (CI: 2.6 – 51.3)
Breaks	4 - 6 hrs vs Other more Frequent Breaks	4.1 (CI: 0.93 – 18.2)
Watching TV	Yes vs No	0.3 (CI: 0.07 – 1.3)
Years Driving	0 - 9 yrs vs 9+ yrs	1.6 (CI: 0.4 – 6.0)

* Independent Variables entered in model: Belt Compliance, Gardening, Watching TV, Speed of driving, Frequency of breaks, and Length of driving.

Table 7.3 shows the results of the model fitting pain after driving amongst back belt users (excludes Combi Terminal). Compliance with use (Yes/No) is substituted for frequency of use and years of driving for vibration intensity.

1. Compliance with the use of back belts indicated that the drivers who wore the belts had a much higher risk of reporting back pain after driving a forklift than those that did not use the back belts. However, as indicated above, the results should be interpreted with care as it may not indicate that the back belts were the cause of the pain, but that drivers who had the most pain after driving may have tended to wear the back belts more in an attempt to prevent or reduce the pain. The association may therefore not be causal.

2.Similarly to findings in table 7.2 drivers who took rest breaks more often than the official breaks had lower risk of developing pain after driving.

3. Again, watching of television was associated with reduced odds of pain after driving. As pointed out above this may reflect confounding effects of the socio-economic gradient, since workers owning a television may be better off than those without.

4. Years of Driving was categorised into two main groups, 0-9 years and 10+ years of driving, due to the small numbers of drivers in certain of the sub categories. The model indicated that drivers who had been driving for 0-9 years had a higher odds of developing pain after driving than the drivers that had been employed for more than 10 years, although this was not statistically significant. The relevance of this finding for a healthy worker effect is discussed in the next chapter.

Table 7.4: Model fitting: Predictors of Pain after driving amongst back belt groups (excludes Combi Terminal) and frequency of use of belts. (Model 4 . n = 149)

Variables *		OR (95% CI)
Constant		
Belt Usage	Never vs All the time	0.06 (CI: 0.06 – 0.03)
	Sometimes/ Rarely vs All the time	0.3 (CI: 0.05 – 1.5)
Breaks	4 - 6 hrs vs Other more Frequent Breaks	5.6 (CI: 1.17 – 23.6)
Watching TV	Yes vs No	0.28 (CI: 0.07 – 1.2)
Years Driving	0 - 9 yrs vs 9+ yrs	2.1 (CI: 0.52 – 8.0)

* Independent Variables entered in model: Gardening, Watching TV, Speed of driving, Frequency of breaks, Back Belt Usage and Length of driving.

Table 7.4 shows the results of the fourth model fitting pain after driving, using the frequency of back belt usage as an independent variable.

1. Belt Usage patterns, When comparing the reported use of back belts all of the time , sometimes/rarely and never, the results showed that drivers that never wore the back belts had a lower odds of developing back pain after driving than those that wore the back belts all the time. Drivers who wore the back belts sometimes/rarely had an intermediate risk. There was thus no evidence of a protective effect of belt usage. Even the reduced risk of "sometimes" users relative to "all the time" was not statistically significant. This negative association of "never use" with pain after driving suggests that the drivers probably wore the back belts only if they experienced back pain, and those that did not have pain tended to not wear the back belts. This may again be attributable to the psychological effect of the back belts on the wearers, in that they tended to comply more with the use of the pain the worse their pain was

2. With regards to rest breaks taken by drivers during their work shift, watching of television and years of driving, the model shows a similar pattern to the results shown in table 7.4 above.

CHAPTER 5:
DISCUSSION OF RESULTS

5.1 Response Rates

In the Portnet study the response rates were high at Point (100 %), and Maydon Wharf (96 %), but low in the comparison group at Combi Terminal (39 %). When these response rates are compared to other similar studies involving professional drivers the response rates in those studies were generally lower, ranging from 71-79 % (Bovenzi 1998, Bongers and Boshuizen 1990). This factor could be attributable to the fact that in most of the other studies the questionnaires were mailed to the respondents and self administered, and in this study the questionnaires were administered in a group interview situation, which would be expected to increase the responses.

The response rates in the two combined (intervention) areas when compared to the control area were different due to factors such as the interference of the end of year vacations in Combi Terminal with the questionnaire administration, as discussed earlier. However, the validity of the study may not necessarily have been compromised, as the non-responders were not expected to be any different to the responders. It was not, however possible to assess empirically if any differences existed so bias due to non-response cannot be entirely ruled out.

5.2 The Prevalence and Severity of Back Pain.

One of the main outcome variables included in the Portnet study was the prevalence rates of back pain amongst the drivers, with various period prevalence rates being compared amongst the groups.

5.2.1 Lifetime Prevalence (pain ever)

Lifetime prevalence was measured in the questionnaire to ascertain the prevalence of back pain amongst the respondents at any stage in their past life, i.e.: had they experienced any type of back pain in the past on a regular basis. This response relied on long term memory of pain in the back, and would be considered to be less accurate than other shorter recall periods such as last 12 months or pain today.

A large percentage (86 %) of the drivers in all 3 areas had experienced back pain at some stage in their lives, and these results were slightly lower than the findings in the study by Riihimaki (1989) at the highest figure of 90%, and higher than the others such as Bongers and Boshuisen (1990), 68 %, Bonger *et al* (1990) at (51 %) , Brendstrup (1987) at 79% and Bovenzi (1998) at 83.8 % and 81.3 %. Nonetheless, the findings in this study are of the same order as other international studies.

5.2.2 Point Prevalence (back pain today)

The point prevalence (pain today) was a question that required the reporting of back pain on the day of the questionnaire administration. Overall point prevalence in the three areas was only 45.5 %, a result much lower than the 12 month and lifetime prevalence periods and would be expected to be much higher as the drivers would find it easier in theory to report on pain felt on the day of questioning when compared to pain felt 12 months ago or over their whole life.

However, the results could have been influenced by the times of administration of the questionnaire i.e.: time of day/during or before work shift etc, as the questionnaire was administered at different times of the day in the different areas due to circumstances such as availability of drivers and work schedules. This resulted in some drivers completing the questionnaire at the mid shift break after a few hours of vibration exposure, and others in the entire control group completing it before their shift had started. Because of time tabling differences no whole-body vibration exposure had occurred in the control group prior to interviews and this may have contributed to the differences in reported back pain (point prevalence).

For these reasons the data for point prevalence were not regarded as sufficiently accurate and the results were not used to assess the effectiveness of the belts in reducing the prevalence or severity of back pain and during preliminary analysis this variable was found to be non-significant.

5.2.3 12 Month Period Prevalence

The 12 month period prevalence was recorded in response to a question that relied on the driver's memory on pain experienced in the back in the last 12 month and generally coincided to the period during which the belts were used by the drivers in the intervention group.

Most studies in the literature report the 12 month period prevalence of back pain. In this study the 12 month prevalence was found to be 85.5 %, which was slightly higher than most of the other studies reviewed, such as Brendstrup (1987), 65 %, Bonger *et al* (1990) 55.6 %, Bovenzi (1998), 82.9 % and 71.7 % and Riihimaki (1989), 82 %.

5.2.4 Severity of Back Pain

No other whole-body vibration studies in the literature tried to quantify the severity of back pain amongst the drivers. In this study the pain numerical rating scale was introduced and allowed the drivers to attempt to quantify the pain severity at its least and at its worst. There was no significant pattern that emerged when the severity of pain was compared to years of driving, with the pain staying relatively constant over the exposure periods. There is thus no indication that the severity of back pain follows a linear dose-response curve.

5.2.5 Location of back pain

The drivers were also required to describe the location of the back pain, putting it into three classifications namely: shoulder area, middle back and lower back (lumbar region). The majority of drivers in the study (79 %) reported pain in the lower back region, which is consistent with the most likely location of back pain reported in the literature. The second most common area of pain was the shoulder area (15 %), and lastly the middle back (11 %). These results indicate an interesting factor in that the shoulder area was reported as a pain area more often than the middle back area. This would generally not be expected as the distinction between lower and middle back can be difficult to make and one would expect results for pain in the middle back area to be closer to the lower back prevalence results and the shoulder area to be the lowest. The above results could be attributed to the way the different areas were indicated to the drivers by the questionnaire administrator, with very clear and lengthy explanation given prior to this question being answered by the drivers resulting in a good distinction between the areas of pain. The shoulder pain experienced by the drivers would not be expected to be due to the effects of vibration exposure, as usually vibration energy would be absorbed and cause damage in the lower parts of the musculo-skeletal system.. This attenuation of vibrational energy would thus offer a degree of protection to the structures higher up on the body such as the upper back/shoulder areas. The pain reported in this area can probably be attributed to the posture that needs to be maintained during driving and the balancing of the head and upper body, as well as the gripping and turning of the steering wheel with the hands and arms out in front of the body.

5.2.6 Duration of Pain (Acute/Variable and Chronic/Constant)

If a driver experienced lower back pain they were then required to report on how long that pain lasted. This was classed into various categories, namely several hours, several days, several weeks, several months or always present. Most drivers at Portnet experienced pain for several hours to several days (78 %) slightly higher than in the study conducted by Bongers *et al* (1990),which recorded 68.9 %. In this study 17 % noted their pain was always present, as opposed to the 6.8 % with constant pain in the Bongers *et al* (1990) study. Thus the nature of the pain at Portnet is such that the majority of the drivers suffered from acute/variable pain possibly related to the driving occupation, that would disappear or reduce in severity after several days or weeks without exposure.

The chronicity of pain was shown to follow an expected pattern with most drivers (56%) showing acute/variable pain and less (44 %) experiencing chronic/constant pain. When the back belt and control groups were compared in this regard the results were similar again with the majority of drivers in the intervention group (56 %) and the control group (59 %) reporting acute/variable pain versus 44 % and 41 % respectively reporting chronic/constant pain. These results could possibly indicate that the acute/variable back pain experienced has a closer link with the occupational activities i.e. forklift driving than with other more long term risk factors for back pain eg: age, that could result in longer term chronic/constant effects.

When the duration of pain was compared between the two classifications (acute vs chronic), it indicated that the percentage of pain that was reported as constant or chronic increased as the reported duration of pain increased as would be expected. This relationship was almost linear in nature as the chronicity related directly to the duration of pain. The results in which 24 % of respondents reported pain for several hours, 36 % pain lasting several days and 57 % pain lasting weeks or longer show this relationship.

With the acute or variable pain experienced by the drivers the relationship was opposite as would be expected, with the reporting of acute or variable pain decreasing as the reported pain duration decreased. The results indicate this clearly again, with 76 % of drivers reporting pain lasting several hours, 64 % several days and 43 % several weeks or longer.

The use of the pain severity rating scales (pain at its worst - pain at its best) to characterise acute versus chronic pain was shown to be a useful tool in the characterisation of pain. from the evidence in the literature this scale has not been used in other vibration studies related to back pain, and could in future form a useful measurement tool for use in other epidemiological studies, especially for future comparison of pain severity results.

5.2.7 Treatment and Medication Taken for Back Pain

The treatment sought or medication taken by drivers specifically for back pain may be an important objective indicator of the severity of the problem of back pain amongst the forklift drivers, as a proxy for pain severity. At Portnet, 57.5 % of the drivers had sought treatment for back pain, which is slightly higher than what was found in most cases in other studies such as

Bonger and Boshuisen (1990), at 31 %, Bongers *et al* (1990), at 33.3 %), Brendstrup (1987),. at 16 % and Bovenzi (1998) at 25.4 %.

However these results could be influenced by other factors such as recall bias, availability of medical treatment and medications etc. For example the results could vary due to the interpretation of the word "treatment", where some of the drivers may interpret seeing a doctor as treatment and others actually staying in hospital or taking medication. In this study treatment was taken as consulting a doctor, physiotherapist, homeopath, and even a traditional healer or Sangoma, of which (28.5 %) of the drivers did, but the majority of drivers (37.5 %) who went for treatment consulted both a doctor and traditional healer. 35 % had taken medication specifically for back pain which may have been traditional or orthodox medication.

5.2.8 Absence From Work

Absence from work or sick leave may be another important proxy indicator of the seriousness of a disease or condition. However, this relies on the accuracy and reliability of the records and proper diagnosis and reporting by the doctor.

The official records at Portnet were not accurate or reliable due to the fact that the codes recorded for reasons that sick leave was taken were so diverse and vague that no accurate information could be gleaned from the records. The records also only were kept for sick leave periods of more than two days, so one full day off sick was not recorded.

Drivers recall of sick leave suggested that 18.5 % of the drivers at Portnet had been off sick from work due to lower back pain in the last 12 months , which was similar to the results of Brendstrup (1987), at 22 %.

The absentee rate in the Portnet study could be attributed to recall bias, as when medical absenteeism records at Portnet were consulted as to reasons for absenteeism (where useful reasons were given such as back pain, lumbago, lower back pain etc), the days lost due to back pain seemed to indicate a higher number in the records than was indicated by the drivers in their questionnaire responses.

5.2.9 Onset of Back Pain

With regards to the onset of back pain after the drivers started driving as an occupation, the Portnet drivers (total) show a trend of an increased prevalence and risk of developing back pain within the first 10 years of driving, with a slight decrease in risk thereafter. This could signify the presence of a healthy worker effect, as seriously affected workers may leave or find another job and the hardier workers continue on and report less pain. This would seem to be unlikely as the drivers that were in the study and that would be considered to the "health workers or health stayers" in fact reported an overall prevalence of 86 % back pain, which can hardly be classified as healthy! Given the high prevalence of back pain, the healthy worker effect would be small , but may be important for severe pain, thereby diluting the results of the reporting of this type of pain. The healthy worker effect at Portnet was however considered, but due to the low turnover of drivers and difficulty in finding other jobs most drivers seem to stay in their job for prolonged periods of time, as discussed with length of driving (section 5.3.2).

5.3 Risk Factors for Back Pain

5.3.1 Age

The mean age of the drivers at Portnet (47.6 years), was fairly close to most of the mean ages recorded in similar studies, 41.7 years (Bongers and Boshuizen 1990), 42.8 years (Musch 1990), 41.2 and 45.8 years (Bovenzi 1998), but significantly higher than the drivers in the study conducted by Riihimaki, 1989, which recorded a mean age of 37.3 years. The mean ages of the drivers overall was fairly old due to the fact that most drivers had progressed or been promoted from other jobs, and forklift driving was seen as a better job than for example being a general worker at the port. Forklift driving was probably in most cases considered by drivers to be the final job before retirement, as Portnet employee benefits such as pension and medical aid are considered to be fairly good.

This would have some important implications for the so called "healthy worker effect", where most older drivers that have been employed for a longer period would be dissuaded from leaving, as this would affect their pensions and have financial implications for their old age. Thus it would be assumed that older drivers that had longer service would tend to remain in the job and any pain experienced would have to be very severe or debilitating before the driver would leave. On the other hand the younger drivers with only a few years service would be expected to be inclined to leave the job more often even when experiencing less severe pain as their job opportunities would be better and their pensionable years accumulated less.

However from the previous results age did not show a positive association with back pain as would be expected, with older workers not reporting more frequent and more severe pain than younger workers. In the multivariate analyses their was also an unexpected non-significant increase in odds ratios for back pain for drivers who had been driving for less than 10 years versus those driving for more than 10 years which does not mesh securely with the dose response theory. Therefore the results may have been influenced by a healthy worker effect however insignificant.

5.3.2 Length of Driving

The mean length of driving forklifts at Portnet, 13.4 years was similar to the other studies by Bongers and Boshuizen (1990) and Riihimaki (1989), which recorded means of 15 years, Bovenzi (1998) of 13.4 years, and Brendstrup (1987) of 7 years. The three test areas also had fairly similar means when length of driving was considered and drivers tended to stay in the occupation for a fairly long periods of time. This could be influenced by two main factors, firstly the economic situation in the country could force workers to remain in the jobs they have due to the difficulty in finding different or new jobs especially for a semi-skilled or unskilled worker, and the high rates of unemployment in South Africa would also influence this decision. This factor would be re-enforced by the fact that Portnet is generally considered to be a good employer with good staff benefits and employee schemes which should result in a lower turnover of staff. The second main reason for remaining in the job for extended periods of time is that the working conditions and driving occupation may in fact be preferable to other jobs such as physical labour and pain, discomfort or musculo-skeletal injuries from driving may be seen as bearable and accepted as part of the job. Pain severity would have a part to play in this decision. The length of driving would be a risk factor for the development and severity of back pain and was considered and controlled for in the comparison of the different cohorts, as exposure duration and vibration intensity gave a proxy indication of exposure dose which is related to the development of back pain and severity of effects.

5.3.3 Sporting and Other Activities

With regards to the level of sporting activities amongst drivers, only 7.5 % of the drivers at Portnet regularly taking part in sports, lower than that reported in the study by Bovenzi (1998), 25.8 %. Being sedentary and not doing enough exercise to allow the back to be strengthened and protected against some musculo-skeletal injuries, is a recognised risk factor for back pain.

Another potential problem might be that many drivers tend to be overweight and have extensive accumulation of fatty tissue in the abdominal region which would also place additional strain on the lower back and increase the risk of injuries and pain. However, the confounding effect of lack of exercise was minimised because the three test areas in the study did not differ significantly in their sporting activities.

Other activities such as gardening were high amongst the Portnet drivers (67 %), and not reported in other studies. The back belt groups did in fact differ in this regard with the control group having an abnormally higher participation in this activity, (90 %). Therefore this factor was considered and controlled for in the statistical analysis and in variable testing for inclusion in the multivariate modelling.

The sedentary activity of watching television was also not reported in other studies, but 29.5% of the Portnet drivers regularly watched television. The results in the back belt and control group cohorts when compared, showed again significant differences, with the control group having lower television viewing habits when compared to the belt wearers. This may correlate with their increased gardening activities as discussed previously. Due to the fact that being sedentary and not exercising enough can lead to an increased risk of back pain, it was decided that this factor could confound the outcome and was therefore included in the multivariate modelling.

When watching television was considered in the multivariate model fitting pain after driving, watching television was protective (OR = 0.5; 95 % CI 0.2 - 1.1) for having pain after driving. This result is unexpected as a sedentary occupation like television viewing would be expected to be a risk factor for the development of back pain. However an alternative explanation may be that watching television offers increased resting time to allow for better recuperation of the back muscles and reduction in lactic acid levels associated with pain, or may also reflect a better socio-economic status, as a mechanism for reducing back pain morbidity.

5.3.4 Prior Occupations

In the Portnet study a very low percentage (7 %) of drivers had been driving prior to working at Portnet, and had been exposed to occupational whole-body vibration, as opposed to the study by Bongers and Boshuizen (1990) which had a much larger prior exposure rate of 43 %. This could be due to the high unemployment rates in South Africa where workers tend to stay in the less skilled jobs they have for a longer period before obtaining the better skilled jobs, and therefore the turnover rate amongst workers in skilled jobs may be lower than in developed countries. Forklift driving is also a relatively skilled job and drivers would tend to remain in the job as long as they can given that other better jobs are difficult to find.

Thus the percentage of drivers that had been involved in general unskilled non-whole-body vibration exposed work prior to forklift driving was relatively high (95 %). This high percentage is also found in the international literature, with Brendstrup (1987) recording 81% in his study, and Bongers *et al* (1990), 81 %. This generally indicates that at Portnet the forklift driving occupation is usually entered as workers move up from relatively unskilled general work into the more skilled and better paid driving occupation. The general unskilled occupations would of course have their own risk factors for back pain that would obviously influence any outcome in a back pain study. Fortunately the potential confounding effect of previous work was limited because the two groups of drivers came from very similar background, and had similar profiles of jobs performed before driving forklifts. This indicates the importance of selection of the groups for this study, such that drivers with previous exposures to back pain risk factors and present exposure to whole-body vibration were compared to a control group of drivers with the same exposure pattern and characteristics.

5.3.5 Driving Speeds

The majority of drivers at Portnet (71.5 %) were of the opinion that they drove at an average speed, as opposed to slow or fast. Malchaire *et al* (1996), found that on average the driving speeds were reduced by approximately 1.7 km/hr when the forklift was loaded and this resulted in a reduction in the RMS vibration levels experienced, by as much as $0.15 ms^{-2}$. The driving speeds were however not empirically recorded or investigated fully in the Portnet study, and average driving speeds were used during the test runs. Therefore the influence of the speed could not be ascertained. The opinions of drivers in this regard were used as a proxy for driving speeds. However, when the two groups were compared the differences between were considered to be insignificant ($p = 0.61$), and the assumption was that the two groups did not differ in driving speeds and therefore the major outcomes i.e.: prevalence and severity of back pain, would not be significantly influenced.

5.3.6 Other Control Measures Used

No other whole-body vibration studies recorded examining the effects of any type of other control measure (whether of a scientific nature or devised by the workers themselves) on the prevalence and severity of lower back pain amongst professional drivers. Seat mechanisms were investigated in some studies by Burdorf and Swuste (1993), and Ishikawa (1998), but these studies investigated the vibration attenuation abilities of the seat, the vibration transmissibility factors and not the health outcomes on the driver. In this study, a small percentage of drivers (8 %) used cushions for extra support of the back, but this is unlikely to have had any significant effect on the whole-body vibration exposure levels as vibration exposure travels through the seat up into the buttocks of the driver and then is transmitted up into the other musculo-skeletal structures of the body where damage can occur. A cushion to support the back would not would not be expected to significantly modify this process or reduce the vibration exposure levels. It may be seen as an attempt by the drivers to modify the ergonomic designs of the forklift seat and may indicate a failure in the design. Amongst the two cohorts the difference in this regard was insignificant ($p = 0.25$), with more drivers in the back belt group using cushions when compared to the control group. This type of "control measure" was not investigated further because of its ineffectiveness in protecting against whole-body vibration, the variations in cushions and methods of use, and because of the small numbers of drivers involved. The use of a cushion and "modification" of the seating on the forklift could probably be classed amongst the different types of seats used on the various models of forklifts and investigated further in a study of the effectiveness of the different seats. However this was not addressed in this study.

5.3.7 Rest Breaks

Regular rest breaks are essential for the recovery and resting of the back muscles and other structures. Most professional drivers do not take regular rest breaks from the sitting posture and have prolonged exposure periods that over stress the affected musculo-skeletal structures. Brendstrup (1987) found that 75 % of drivers in her study drove 6 -8 hours per day. However, the shifts at Portnet vary from 8 to 12 hours with rest breaks half way through the shift. Thus drivers do not rest regularly enough to allow recovery and recuperation of back muscles and structures. This not only increases exposure doses but reduces the exercising or resting of the back muscles, and the diffusion of nutrients into the intervertebral discs necessary for repair.

Obviously other minor breaks are taken during the shift for example, when work is stopped for some reason, or delayed or when workers are waiting for a ship to dock. However, these are irregular and of indeterminate frequency and length, and cannot be relied on as a protective break for rest and recuperation of the back structures. In fact, some drivers indicated that when an important job was to be carried out and other ships were waiting to dock then very few or no breaks were taken until the job was finished. The two cohorts did not differ significantly as to when the breaks are taken with most drivers in the two groups merely indicating a mid shift break. However, slightly more drivers in the back belt group indicated that they took breaks at other times during the shift. Multivariate modelling showed that drivers who took breaks more frequently did in fact have a lower odds ratio for back pain after driving (OR = 0.2; 95 % CI 0.07 - 0.6) when compared to the drivers reporting only mid shift breaks. This would make sense for two reasons, one being that their exposures would be slightly lower because of reduced exposure times, and secondly because increased rest breaks would allow for better rest and recuperation of the back and its structures and should lead to less severe pain or a reduced prevalence.

5.4 Compliance and Frequency of Use of the Back Belts by the User Group.

In this study compliance of drivers with the use of back belts was higher (90 %) than expected, probably due to high motivation. Workers had actually requested the belts instead of being forced to use them. With regards to the frequency of use of the back belts by the drivers overall, most drivers (76 %) in the two areas where belts were issued wore the belts all the time whilst driving, which is a good indication of their belief in the effectiveness of the belts and their acceptance of the devices. Less drivers wore the belts sometimes or occasionally and very few rarely or seldom. Amongst the back belt wearers the frequency of use and the compliance with use were very closely correlated to the reporting of pain. The driver's use of the belts and their frequency of use increased with increasing reported back pain. One explanation may be that the belts had a powerful psychological effect on the drivers who wore the belts more frequently if they had a lot of pain. Another explanation may be that the belts actually damaged the musculo-skeletal integrity of the back and caused increased pain.

This was an important area of investigation for a number of reasons. Firstly compliance with use was confirmed in order to ensure that the intervention under study (back belts) had actually been used by the drivers to an extent that they could have had an effect on the dependent variables, the prevalence and severity of back pain, so as to ascertain their effectiveness. Secondly frequency of reported use was used to estimate dose-response relationships. This was very important in dealing with confounding, by vibration intensity exposure by area, and is discussed in more detail. Thirdly, frequency of use may be used as a proxy of acceptance of the devices by the drivers and reflect ease of use and comfort factors.

There were small differences in compliance with use between Point (94 %) and Maydon Wharf (80 %). This may have arisen because the belts were worn for a slightly longer period before the administration of the questionnaire in the Maydon Wharf area, compared to Point where the questionnaire was first administered. It would therefore be expected that more loss, theft, and breakages would occur with the longer use periods and this may explain lower compliance in Maydon Wharf. This factor could not be entirely controlled for in the analysis.

5.5 Characterising Vibration Experienced in Typical Driving Activities.

The pilot study on a sample of forklifts had a number of motivations. Firstly it provided an indication that the vibration levels at Portnet when compared to international standards did in fact justify the concern for back pain reported by drivers. All areas had high vibration levels that exceeded the European Union Machinery Directive standard of 0.5 ms^{-2} (See section 4.5.2 for details). Therefore the reporting of pain was not merely as a result of other non-classified or unidentified factors such as internal politics, conflicts or job dissatisfaction but was quite likely to be related to real exposure to whole-body vibration..

The second reason was to obtain a proxy measure of the vibration exposure characteristics in the three different areas in order to attempt to quantify whole-body vibration exposure as an important risk factor. This would further enable estimation of vibration dose-response relationships that may be present. The Portnet vibration results were also compared to international studies carried out overseas in order to ascertain an indication of the position of the conditions at Portnet in comparison to global exposure.

Lastly the information for Portnet was useful in implementing ongoing control measures for whole-body vibration at the port. The sub-study was intended to assess the effectiveness of the equipment at Portnet, notably the effectiveness of the different seat types in attenuating vibration and protecting the drivers using SEAT % transmissibility values, and identify the effects of the driving surface on vibration intensities and exposure. In addition, comparisons between the different forklifts in use at the port also aided in future choice and purchase of forklifts that would have the best vibration attenuation and driver protection controls and not merely the best productivity characteristics (such as power output, load bearing abilities and fuel economy). Other useful observations during the study of practices, operating procedures and policies at Portnet, that would also reduce exposure and increase protection of drivers were pointed out and recommendations made to the risk control section.

5.5.1 Possible Confounders and Limitations of Vibration Results

The results of the vibration measurements were limited in their application due to the various limitations discussed earlier i.e.: financial and time constraints, as well as the fact that due to logistical problems measurements could not be taken under operational conditions with real work being carried out due to logistical problems. The number of forklifts tested was low and the selection of the forklifts included in the study was not random, as a result of the problems experienced on the days of the measurements. Thus the vibration data cannot be applied with any degree of certainty to the whole population of forklifts or exposure conditions existing in the different areas at Portnet. These limitations need to be borne in mind when interpreting these results and caution exercised when applying them to the working conditions at Portnet. Nonetheless, some inferences can tentatively be made as to the probable exposure conditions and the implications for assessing the effectiveness of the seats of the forklifts. Overall indications of probable exposures can be ascertained when the average mean vibration levels in the three areas are compared to the EEC machinery directive standard of 0.5 ms^{-2}.

5.5.2 Vibration exposure

The European Union Machinery Directive poses a threshold level for vibration, i.e.: the exposure value below which no adverse effect on health and safety is expected at an 8 hour exposure of < 0.25ms^{-2}. The action level (i.e: the value above which technical, administrative, and medical provisions must be undertaken) is 0.5ms^{-2}, and the exposure limit (i.e: the exposure value above which an unprotected worker is exposed to unacceptable risks) is set at 0.7ms^{-2}.

When the results were modelled for typical operational conditions, at the Port, with seats unadjusted for weight on a rough driving surface, the mean whole-body vibration values (RMS in ms^{-2}) were Point (1.9 ms^{-2}), Maydon Wharf at (1.3ms^{-2}) and Combi Terminal at (1.1ms^{-2}) which all exceeded the exposure limit of the EU directive, exposing drivers to unacceptable vibration exposure risks. With these whole-body vibration levels, it is not surprising that back pain and other musculo-skeletal problems were reported by drivers in the three test areas.

The Portnet vibration exposure results correspond to many other studies with similar values on forklifts and other vehicles, Bongers and Boshuisen (1990), 0.8ms^{-2} on forklifts, Bongers *et al* (1990), 1.4ms^{-2} on wheeloaders, Bovenzi (1998) 0.24-0.71ms^{-2} on buses, and 0.89-1.41ms^{-2} on tractors.

5.5.3 Seat Effective Transmissibility Values. (SEAT %)

The SEAT values indicate to what extent the seat of a vehicle will offer protection of the driver against whole-body vibration exposure, by attenuation and reduction of the vibration transmitted from the chassis of the vehicle into the body of the driver through the seat.

From the sample of forklifts tested at Portnet some had very good attenuation values under all operational conditions and even with the seat unadjusted on the roughest surface, eg: forklift

G which fared the best had an average attenuation value of 50.6 %, or reduced the vibration transmission by 49.4 %. The worst forklift was forklift F, with an average SEAT value of 155.4%, or amplification of vibration levels by 55.4 %.

On average the forklifts in the 3 areas under all the test conditions (rough/smooth, adjusted/unadjusted) still had an average amplification of vibration levels of 46.5 %. and not attenuation of vibration as would be expected. The seat unadjusted average value with the vehicle driven on a rough surface, which equates to the normal situation at Portnet was 50 % amplification of vibration levels. An unexpected result was found when the seats were all correctly adjusted, to the weight of the driver and the manufacturers specifications. The seats did not attenuate the vibration levels, but amplified it by 43 %. This is slightly better than for unadjusted seats (50 % amplification), but not offering the protection required or assumed. These findings both indicate a poor performance of the forklift seats even in some of the more recent models with the seats correctly adjusted for the drivers weight, as well as point to vast differences between devices.

When the three test areas are compared with the seats of the forklifts adjusted, forklifts in Combi Terminal had an average vibration attenuation (transmissibility factor) of 10 %, whereas the vehicles in the other two areas did not fare as well, as even with the seats correctly adjusted the vibration exposure of the driver was not reduced but in fact amplified in both areas, Point 14 % and Maydon Wharf 46 %. These variations may not be a true reflection of the actual attenuation ability of the vehicle seats in the three areas for two main reasons.

Firstly in the Combi Terminal area one of the vehicles (forklift G) tested had extremely good vibration attenuation (see appendix J) as it was a very new top of the range vehicle that incorporated a number of new technologies in vibration control. These included a drivers cab "floating" on gel filled shock absorbers, a specially designed low vibration hydraulic gearbox, and a specially designed seat with its own shock absorber. The vibration results from this forklift although only from a very small sample of one forklift of this type, would be very useful to Portnet for future choice and purchasing of forklifts to reduce driver exposure.

Secondly these seat transmissibility results were not a true reflection of the actual conditions that prevail at Portnet as drivers do not adjust the seats for their weight, and therefore the adjusted results merely give an indication of how effective or ineffective the seats are when adjusted according to the manufacturers specifications. The results for unadjusted seats would be more a accurate reflection of normal operational conditions at the port in all three areas as drivers did not adjust the seats routinely. In fact some of the seat adjustment mechanisms were so corroded that they had to be adjusted using vice grips to allow for the adjusted measurements to be conducted. Forklift G again fared very well and this reduced the overall SEAT % values in Combi Terminal. However when the three areas are again compared all areas had an average amplification of vibration and not attenuation, Point 2%, Maydon Wharf 38%, and Combi Terminal 3%. This indicated that all the forklifts in the sample from all three areas evaluated under normal operating conditions on average had an amplification of vibration as it travelled from the chassis of the vehicle and up into the driver, and the assumption that the seats actually offered some sort of protection was incorrect.

When the forklifts from the areas were compared, the vibration results from Point and Maydon Wharf were combined, and then compared to the control group at Combi Terminal, the SEAT % values were higher by 17% in the combined group, when compared to the control group. Due to the small number of forklifts evaluated the results could have large unquantifiable variations as they could have been influenced by numerous indirect non-vehicle related factors on the day of the vibration assessment, such as different driving speeds during the test runs, differences in driving styles and habits, slight variations in driving surfaces, etc.

The effectiveness of the forklift seats in vibration attenuation obviously affects the vibration exposure of the drivers and is a potential confounding factor if the SEAT % values are significantly different overall in the study areas. However, this factor varies so much from vehicle to vehicle, driver to driver, and surface to surface that it would be impossible without hundreds of measurements to quantify exactly the potential for confounding. Given the tremendous variability of this factor, it is difficult to assess wether driver characteristics, driving environment and other conditions were different across the three test areas, and therefore the extent of any possible confounding. The SEAT % values in the three areas did not however differ significantly when compared ($p = 0.24$), nor did the two groups when compared ($p = 0.83$).

The use of the SEAT % Transmissibility value is not a new concept, and has been used to gauge the effectiveness of seats in attenuating vibration in a number of other studies. Malchaire *et al* (1996), investigated the effects of a "normal seat", versus an "anti-vibration seat", and noticed an amplification of the vibration of 7 % with the "normal" seat, and a reduction of vibration of 27 % when using the anti-vibration seat. The difference between the two was 0.6 ms^{-2}. Burdorf and Swuste (1992) also investigated the performance of the seats of 11 industrial vehicles ranging from road transport lorries and tractors to forklifts. They found that many of the best suspended seats available actually increased the vibration levels, and they concluded that most suspended seats do not reduce vibration to safe levels.

5.5.4 Driving Surface

Driving surface has a significant role to play in the drivers vibration exposure, with rough surfaces having a marked effect on vibration levels. In the three areas, the results of the vibration measurements on the different surface areas were as would be expected higher on the rough surfaces (average RMS = 1.4 ms^{-2}) than the smooth surfaces (average RMS = 0.85 ms^{-2}) in all three areas of the study. This is an increase in the average RMS of 0.55 ms^{-2} when moving from a smooth surface to a rough surface, which is significant in that even on the smooth driving surfaces at Portnet, on average the EEC Machinery Directive vibration exposure standard of 0.5ms^{-2} is exceeded. When on a rough driving surface the RMS value close to doubles again, effectively doubling the exposure of the driver. This indicates the importance of the maintenance of the driving surfaces to as smooth as possible to reduce the road surface produced vibration. However as we can see this in itself will still not be enough to reduce the vibration exposure to a satisfactory level to at least below the EEC Machinery Directive standard.

5.5.5 Loads Carried

Malchaire *et al* (1996) discussed the effects of a load carried on the vibration levels that can be attributed to the driving speeds, and they point out in their findings that a reduction of 0.15ms^{-2} was obtained in the RMS value when the forklift was loaded. In the Portnet study the one test run conducted with a loaded forklift resulted in a reduction of 0.24ms^{-2} RMS. However as this was the result of only one test run this result should be interpreted with caution. However it does give an indication that the vibration levels will be slightly lower when the forklift is loaded, and the speed is reduced.

5.6 Attitudes, Opinions and Beliefs Regarding Back Belts Amongst Users.

5.6.1 Comfort and Fit

The nature of the belts and their use lend themselves to problems with comfort, as the tight fitting nature of the device constricted around the abdominal/lumbar region of the back makes for a setting that could become hot and uncomfortable. However approximately equal numbers of drivers found the belts hot and uncomfortable as found them comfortable (33 % vs 31 %). Almost a quarter of the drivers (24 %) felt the belts were too much trouble to wear, but given the high compliance figure (89 %) probably still grudgingly wore them for want of something else. A high proportion of the drivers (83 %) felt that the belt fitted them well. However this question could have been misinterpreted in that a tight fit as is the nature of the belts could be seen as a good fit, but this tight fit can cause other problems, which was indicated anecdotally by many drivers, that the belts tended to split and the stitching parted. Many drivers commented on this aspect and the quality of the belts in the comments section of the questionnaire and 20 % of drivers indicated that their belt was in fact broken.

5.6.2 Effectiveness in Reducing Pain

Amongst the two belt wearing groups a large proportion (81 %) commented positively on the effectiveness of the belt in reducing their back pain. However this result must be viewed with caution in light of the analysis that suggests that the prevalence of back pain amongst the belt wearers was in fact higher than amongst the non-wearers. Some bias of workers towards the use of the back belts would be expected, as they had requested them through their unions originally and would thus have a positive attitude and feelings about their use and effectiveness, and this would influence their responses on the questionnaire. Even though the majority of drivers felt that the belts were effective in reducing or preventing back pain, other responses (i.e: the reduction in severity and prevalence of the pain) showed otherwise. Thus the outcomes that measured in the study were investigated using different questions in the questionnaire and scales of measurement that would enable quantification of the outcome and not merely rely on opinion subject to the bias of the drivers.

However the belt wearers experienced pain that was less severe in nature to those of the non-belt wearing groups. The seemingly confusing results may be explained by the fact that opinion type questions may be more subjective than other types of questions such as a pain severity scale, and may be influenced by many other factors, including the placebo effect. This inference is supported by the fact that the majority of users (88 %) still felt the forklift seat needed to be changed to reduce the vibration or pain from driving, so they felt the belts may help in some way, but were still seeking other solutions to their pain. Twenty-two percent stated that they would rather use something else other than a back belt to prevent their back pain, but these "other measures" were unspecified, and could have included cushions, traditional medicines or western medicines.

5.6.3 Knowledge on back belt use

A surprising 10 % of the users of these belts stated that they did not know how to wear the belt, and this probably would be unexpected in that they are a very simple device to put on, but they still have to be positioned correctly. No formal training in their use or fitting was given by

Portnet, on the assumption that belts can only be worn in one way. However the researcher observed a few drivers that had the belts incorrectly placed or positioned. This strengthens the view that any person provided with any personal protective device needs also to be provided with suitable training on the proper maintenance and use of the device no matter how simple.

5.6.4 Beliefs

Various studies reviewed earlier indicated that when these devices are worn and then especially if their use is discontinued, the risk and prevalence of back injury increases above the original level when no belts were worn. This finding may be supported in the responses to the question in this study regarding back muscle strength, where a surprisingly large (67 %) number of drivers felt the belt actually strengthened the back muscles and only a low (11 %) felt the belt weakened the muscles. This trend is something that needs to be taken into account especially if the users of these belts were to take on manual lifting tasks or duties, as the belief that the back is stronger may cause the user to lift loads that are too heavy resulting in back injury. A low percentage (6 %) felt that the back belt actually made the pain worse.

5.7 Back Belts and Back Pain (Bivariate Analysis)

Amongst the two groups in the study the lifetime prevalence of back pain was higher amongst the belt users versus the control group (92 % vs 80 % Prevalence Ratio = 1.2; 95 % CI 1.0 - 1.4). This was similar for 12 month prevalence (91 % vs 80 % Prevalence Ratio = 1.2; 95 % CI 1.0 - 1.4). The point prevalence showed a lower Prevalence Ratio for the controls versus the back belt group (42 % vs 49 % Prevalence Ratio = 0.9; 95 % CI 0.6 -1.2), possibly due to the differences in questionnaire administration times in the back belt and control groups i.e. back belt groups at the mid-shift break, and controls before the shift started, resulting in less pain reported at the time of the questionnaire administration (point prevalence).

With regards to any back pain confounding should be considered. The back belt group could have had more pain to start with than the control group and thus more reason to try and resolve their problem. However without a base-line study this cannot be verified. Another reason for the increased prevalence and odds ratio amongst the belt wearers could be reporting bias. The issuing and use of back belts could have drawn the attention of the drivers who wore belts to their back problems, leading them to report more back pain than the control group. Thus we cannot assume that the back belts in fact made the pain more prevalent through mechanical action, but it may have had a psychological effect on the drivers reporting of pain. This result would thus be valuable to ascertain whether or not the prevalence of back pain decreased in the belt wearers over the time they were worn as compared to the non belt wearers, and to see if the prevalence decreased amongst the belt wearers when compared to pain ever in the past. The prevalence ratios for taking medication amongst the back belt and control groups (39% vs 31% Prevalence Ratio = 1.3; 95 % CI 0.8 - 2.1) supported the lifetime and 12 month prevalence ratios with the back belt group showing a higher prevalence ratio for taking medication for back pain. The absenteeism from work due to back pain again showed this relationship (22 % vs 15 % Prevalence Ratio = 1.4; 95 % CI 0.6 - 3.1) with the back belt group taking more time off work. These results show a consistency for increased prevalence of back pain and indirectly related factors such as increased absenteeism and increase in the taking of medication for back pain amongst belt users. It must be borne in mind when interpreting these results that Combi Terminal had a poor response rate (39%) and belt users included in the study were included on the "intent to treat principle" which could have had an influence on the results.

5.7.1 Severity and Location of Back Pain

In contrast, when the two groups were compared on severity of the pain, it was interesting to note that the back belt group reported experiencing less severe pain than the control group. Thus although the back belt group reported more prevalent pain, the back pain at both its least and most severe was reported as less severe than the worst and least pain reported by the controls. These results may have been influenced by the psychological or placebo effect of the belts with more objective indicators of the presence of pain such as consulting a doctor ($p = 0.9$), taking medication ($p = 1.5$) or taking time off ($p = 1.5$), the differences between the groups are not significant, which perhaps indicates that the pain severity differences between the groups could be attributable to the placebo effects of the belts.

The back belt group did not differ from the non belt wearer group as far as the location of pain was concerned as the majority of drivers in both groups (83 % vs 62 %) had suffered pain in the lower part of their back, which confirms the results of other similar studies specificity and indicates the specificity of the pain experienced by forklift drivers. The two groups did differ significantly with regards to shoulder pain experienced (11 % vs 31 %), and the back belt group had a lower prevalence ratio (0.4 ; 95 % CI 0.2 - 0.7) when compared to the other group. This could perhaps be explained by the high prevalence of lower back pain amongst belt users detracting from the pain experienced in other parts of the back thereby reducing the reporting of that pain. The psychological effects of the belts could have influenced this reporting in that the belts may have drawn the attention of the belt wearers to the lower back area more then other areas and reduced the reporting of pain in other areas of the back.

5.7.2 Occupationally Linked Exposure/Effects (Back Pain After Driving)

An attempt was made to link the development of all back pain and lower back pain specifically to the driving occupation or activity, by asking the drivers if they experienced pain during or shortly after driving, and in the Portnet study a large percentage (84.5 %) of the drivers experienced back pain during or shortly after driving a forklift.

Amongst the two groups there were slight differences amongst the drivers, with the back belt group in both cases reporting slightly more pain after driving (PR 1.2; 95 % CI 1.0 - 1.4), and more lower back pain after driving (PR 1.4; 95 % CI 1.0 - 1.7). This could be due to a number of reasons, including the psychological effect of the belts and the belts drawing driver's attention to the lower back area.

Secondly, the fact that the drivers in the back belt group had been driving already on the day of the questionnaire administration when completing the questionnaire (at the mid shift break), while the control group had not been driving, could have affected the reporting in the two groups. A recently exposed driver would be expected to be more prone to increased reporting of pain after driving when compared to a fully rested driver arriving for work in the morning. The prevalence ratios from this response are therefore higher than the prevalence ratios recorded on the questions relating to the 12 month prevalence (OR 1.2; CI 95 % 1.0 - 1.4) and lifetime prevalence (PR; 1.2 CI 95 % 1.0 - 1.4). The high overall percentage of reported back pain after driving amongst all the drivers however suggests that most of the back pain experienced by the drivers is experienced during or shortly after driving a forklift and can likely be attributable to the occupation of professional forklift driving as the main cause of the occupational back pain experienced by this occupational group. Twisting and other repetitive movements experienced during the driving activity would also increase the prevalence and severity of the pain experienced.

5.7.3 Chronicity of Back Pain

It was important to assess the chronicity of the pain experienced by the drivers which would firstly give an indication of the pain experience the drivers had to endure and allow a better characterisation of the back pain. The classification of pain periods into hours, days, weeks or permanent allowed the pain durations to be assessed and indicated whether the pain was of acute/short term or chronic/long term nature. This allowed certain inferences to be made about the possible physiological effects of vibration on the drivers, where short term pain symptoms could probably be directly linked to prolonged driving and muscular fatigue and lactic acid related pain. Long term/chronic pain could indirectly indicate more serious deep seated musculo-skeletal injury and effects that are possibly permanently present. These pain experiences could also be linked to severity of the pain and problem.

In the two groups of this study the back belt group showed pain of a longer duration when compared to the controls with 28 % vs 16 % of the drivers having pain lasting from several weeks to always present. The controls conversely had pain of a shorter duration compared to the belt group with 84 % vs 72 %. It is very difficult to infer any biologically plausible explanation for this effect, but it may indicate some sort of psychological effect of the belts whereby the belt wearers could be more aware of the pain because of the belts drawing their attention to the back area. It could also be possible from a biological point of view that drivers experience two types of pain after driving. The first of a short duration that is caused by the build up of lactic acid in the muscles while trying to maintain balance of the body during driving, and this type of pain would be reduced or eliminated after a period of muscular rest. The second type of pain could be linked to vibration exposure directly where the deeper skeletal structures are damaged and the effects are of a long term nature resulting in permanent injury and chronic long term pain with a lower severity.

Back belt users were more likely to have a longer duration of pain with less fluctuation in severity and experienced a more constant type of pain. However, it was less severe than in the non-belt wearers. This effect is interesting as it suggests that belts may have a slight influence on the reduction of pain severity but not on prevalence rates, this could also be influenced by the placebo effect of the belt on the drivers reporting of pain. Again a biologically plausible explanation is difficult to identify, but perhaps the belts offer some sort of support that is linked to the muscular fatigue effects and build up of lactic acid resulting in less muscular pain and thus a lower severity of pain. However, the long term deep skeletal/spinal damage may not be reduced by the belts as they do not offer protection against vibration energy, and thus chronic long term pain prevails and remains. In summary the belts may offer some support to the muscles of the back that are used in maintenance of body balance during driving and result in a lower lactic acid build up and less pain over the work shift. However, they may not offer any protection against vibration and still allow musculo-skeletal injury and damage that results in long term chronic pain. These inferences should however be viewed tentatively due to the potential unknown placebo effects of the belts on the drivers.

5.8 Do Back Belts Reduce the Prevalence of Back Pain?

5.8.1 Predictors of Back Pain

The backward stepwise logistic modelling procedure was used to identify significant independent risk factors associated with back pain. The independent variables and known confounders were identified in bivariate analysis and those included in the model were work area, group (belt wearers versus controls), belt compliance, frequency of use, gardening, watching television, driving speed, frequency of rest breaks, vibration intensity, age and length of driving. Some of the independent variables were highly correlated e.g: length of driving and vibration intensity, and they were not used together in one multivariate model but were alternated sequentially in order to ascertain there individual effects.

Compared to non-users the use of back belts appeared to be associated with increased risk of back pain after driving (OR 2.3; CI 95 % 0.8 - 7.4) if worn all the time, and the risk of developing back pain after driving increased if the belts were only worn sometimes (OR 4.0; CI 95 % 1.6 - 9.7), even when controlling for breaks taken during the working shift, the watching of television, the vibration dose received and age.

5.8.2 Confounding

The higher vibration levels recorded in the belt wearing areas could confound pain levels, prevalence and severity, as an increase in vibration exposures may be expected to increase back pain. However, given the strong odds ratios for back pain amongst belt wearers the confounding would have had to be very strong to explain away the odds ratios. It may still have been possible that small levels of effectiveness of the belts may have been masked by the confounding by vibration exposure. When compliance with belt use was examined amongst those in the belt exposed cohort in the multivariate model, it was found that drivers who wore the back belts all of the time had a lower odds ratio (OR 2.3; CI 95 % 0.8 - 7.4), i.e odds of having back pain after driving a forklift, than the group who only wore the belts sometimes (OR 4.0; CI 95 % 1.6 - 9.7), compared to non-users. Two conclusions may be drawn, firstly, the restriction of the analysis to the exposed group only (Maydon Wharf and Point) controlled for the confounding effect of whole-body vibration exposure, and still generated an increased Odds Ratio for back pain after driving amongst users compared to non-users. Thus increased whole-body vibration experienced in Maydon Wharf and Point drivers could not have explained the elevated risk of back pain amongst back belt users. Secondly, there was an uneven dose-response relationship for frequency of back belt use and back pain. The almost doubling in odds suggests the belts did offer some protection within the belt wearing groups related to the frequency of use or compliance. However this could also be affected by the fact that drivers who wore the belts all of the time could also have had good compliance with other protective factors such as adjustment of seats before driving, reduced driving speeds and taking regular breaks, all of which would also reduce exposure and the prevalence and severity of pain. The model again showed that drivers who tended to not have back pain were the ones that also tended to not wear the belts at all or very seldom/rarely. This may indicate a potential psychological effect that the belts may have exerted on the drivers who did wear belts as they tended to wear the belts all or most of the time if they had back pain.

Moreover, the bivariate analysis (table 4.7.1) showed no evidence of any protective effect with increasing frequency of usage, amongst the user groups. Thus confounding, if present, must have been relatively small in this study.

The fact that the models for all the outcomes (see section 4.5), gave similar predictors is also important for striking out confounding.

When the three test areas were compared in the model Maydon Wharf had the highest odds of developing pain after driving (OR 7.9; CI 95 % 2.2 - 28.2)when compared to the control group, and Point slightly lower (OR 3.4; CI 95 % 1.3 - 8.6) after controlling for the other variables. On the strength of these results it can be seen that although the two belt wearing groups were not equal in all respects to the variables included in the model, they did in fact still have high odds ratios that suggests the back belts did not offer adequate protection if any at all when compared to a non-belt wearing group. In this model differences in vibration intensities/dose between the areas, were also controlled for.

5.8.3 The Healthy Worker Effect

In any epidemiological study the healthy worker effect needs to be identified as a possible confounder, and eliminated or controlled for as much as possible. This effect could adversely influence the outcomes especially in an intervention study, and was considered for this study. The healthy worker effect was considered to have a minimal influence on this study, as factors such as the mean onset of back pain, mean age and length of driving indicated that the drivers tended to stay in their job for long periods of time and driver turnover rates were low.

However, the lack of a clear dose response relationship with age and years of driving indicates that a healthy worker effect could have been possible and cannot be completely ruled out. (See sections 5.2.9, 5.3.1 and 5.3.2 for more detail).

Table 8.1: Bradford Hill analysis of possible causality that back belts offer protection against back pain.

Strength of Association	NO	Odds Ratios were increased for belt wearers.
Consistency of Findings	YES	Two groups had consistent increase in Back Pain.
Biological Plausibility	NO	No clear biological explanation for increase in back pain.
Temporal Sequence of Exposure and Effect	YES	Exposure to the back belts preceded the effects, but back pain may be associated with other causes eg: psychological or placebo effects.
Dose-response Gradient	NO	No clear association, slight reduction in pain severity with increased belt use.
Specificity of Risk Factor for Outcome	NO/YES	Back pain difficult to associate with specific cause/exposure.
Coherence of the Evidence	YES/NO	Some coherent with previous knowledge.

(Source: Hill, 1965)

The Bradford Hill Criteria can be used as a concise and practical description of causal inference procedures in epidemiology (ILO 1998), and can be used as a guideline to assess the exposure disease relationship. From the seven criteria shown in table 8.1 above only two can be seen to clearly give a positive answer to the questioning criteria, with the majority being negative or borderline.

From the foregoing evidence it can be reasonably inferred that due to the uncertainty in the causal inference related to the use of and the effectiveness of back belts in reducing the prevalence and severity of back pain, it can be assumed that the use of back belts does not offer any significant protection against back pain, and may increase the reporting of back pain amongst users of these devices.

5.8.4 Shift Work

Shift work should be considered in any occupational epidemiological studies as a potential confounder, however in this study upon consideration it was decided that it was not a major confounder, as all drivers in the study worked shifts of the same schedule and duration both in the back belt and control group and the effects of shift work could be assumed to be the same on all the drivers in the study. This factor would have been more important if the exposed drivers were compared to an unexposed group such as office workers who do not work shifts, and it may then have had an influence on questionnaire responses and reporting of pain between the two groups. However, this was not the case in this study and this factor was not pursued further.

CHAPTER 6: CONCLUSIONS AND RECOMMENDATIONS

6 Conclusions

With the ever-increasing cargo traffic through Durban harbour and the increasing need in general industry for more forklifts, increasing numbers of professional drivers are likely to become exposed to unsafe levels of whole-body vibration. The use of back belts amongst drivers suffering from occupationally related back pain also appears to be increasing as the untested assumption of the effectiveness of these belts spreads within the industry and is perpetuated by the vendors of the belts for driving activities.

Data from this study indicate that great caution should be exercised when considering these devices for use against whole-body vibration, as the evidence for their effectiveness in offering adequate protection against back pain caused by vibration is doubtful. However the evidence that forklift drivers do have a legitimate complaint regarding the high prevalence of back pain is much stronger, given the high levels of whole-body vibration encountered and poor ergonomic conditions. These needs to be addressed in a holistic manner that encompasses all the well tested principles of ergonomics and occupational hygiene. By addressing the engineering aspects of control such as vehicle design, seat design, vibration attenuation, driving surface and speed limitations much of the vibration exposure and ergonomic hazards can be reduced and the adverse health effects should then follow suit. Administrative controls should then be followed such as the implementation of good policy and practice regarding vibration issues, limiting driver exposure, and implementing driver training and ergonomics programmes and perhaps more rest breaks that could include exercise programmes.

The use of back belts cannot be recommended as a legitimate control measure against whole-body vibration exposure and other more direct and proven methods of driver protection should be implemented.

6.1 Limitations of the Study

In any study there are limitations that need to be considered and accounted for as far as possible when interpreting any results, and they should be taken into account as they could affect the validity of the findings.

6.1.1 Due to problems encountered with the issuing of back belts during the planning phase of the study, no base-line study could be carried out before belts were issued to allow proper characterisation of the change in health status in the intervention and control groups across the intervention. A before-after comparison would have enabled quantification and identification any inherent differences between the two groups that could have had a confounding effect on the outcomes.

6.1.2 Due to the fact that an anonymous questionnaire was requested by the participants in the study for fear of being identified individually, no linkages could be made to forklift variables critical to whole-body vibration. Thus it was difficult to characterise exposure for individual subjects accurately to inform assessment of dose-response effects in relation to whole-body vibration exposure.

6.13 A further weakness in exposure characterisation due to vibration measurements conducted on only a small sample of forklifts within the three areas and vulnerability of results to outliers. Many more measurements should have been taken but this was not possible due to the budgetary constraints. The proxy vibration measurements calculated from the pilot phase of the study were taken on different vehicles in different areas with different drivers and the measurements were not done during actual working conditions due to the logistical problems experienced and discussed previously under the limitations of the vibration measurements.

6.14 Lastly the reasons for non-responders in the Combi Terminal area is unknown, and without data on non-responders we cannot rule out differential distribution of key confounders.

6.15 Certain other potential confounders (shift-work, time of examination, date of examination, other unrecognised vibration control measures used by drivers, individual motivations and biases, and other influencing factors), could not be controlled for because there was either no data available or unreliable data for these variables. However, there is no evidence in the literature that these would be expected to be powerful confounders.

6.2 Recommendations

In view of the above findings and in order to reduce vibration exposure levels to as low as possible, this study recommends the implementation of a comprehensive occupational hygiene programme which should incorporate a holistic view of all aspects and factors both direct and indirect that may have an influence on the production, transmission and the exposure of the driver to whole-body vibration. In order to control whole-body vibration successfully the recommendations include the use of existing practices, procedures and technologies. However certain areas needing further development are also included. The following specific measures can thus be recommended:

6.2.1 Engineering Controls

6.2.1.1 Seats

The Seat of a forklift obviously plays a very important part in driver protection not only from a vibration attenuation point of view, but ergonomically by designing the workplace (seat) to suit the worker (driver). Various aspects identified in this study need to be considered for this important control measure namely :

- The best solution would be to redesign the seats of the forklifts to improve their attenuation and ergonomic properties. This cannot be done on an ad hoc basis as it requires special engineering and ergonomic knowledge, and testing equipment in order to ensure that the design specifications do in fact improve the situation and offer correct driver protection even under severe operational conditions.

- These new improved seats then need to be retrofitted into the older forklifts. If Portnet plans to use the existing older forklifts for any length of time they need to consider this as an interim control measure until better forklifts are purchased.

- Seats that are incorporated in new forklifts that are purchased in the future must be accompanied by manufacturer's specification and performance information. Ergonomic seat design and vibration attenuation performance results and information should be demanded by the purchaser in much the same way as specifications available for engine performance. This will ensure that care has been taken with the design of the seat and will result in better driver comfort and less adverse health effects, sick leave, medical costs and lost time. Manufacturer vibration seat attenuation performance results should be obtained from field testing of vehicles under different terrain and operational conditions and not merely from laboratory testing.

6.2.1.2 Driving surface

Driving surface has a significant role to play in the drivers vibration exposure, with rough surfaces having a marked effect on vibration levels. It is thus important to ensure that all driving areas are rendered as smooth as possible and maintained in this condition. This applies specifically to Maydon Wharf which has very poor external driving surfaces. Maintenance will obviously include internal and external road surfaces, and should also incorporate some sort of level crossing points clearly marked where road obstructions such as railway lines, drains etc have to be crossed. Forklifts can then drive carefully and slowly over these level crossing points and avoid the vibrational shocks normally associated with the crossing of these obstructions which increase the vibration exposure dose.

A properly planned and scheduled maintenance programme has to be incorporated into the overall management and maintenance plan and regular inspections and maintenance needs to be carried out to maintain the surfaces in a good condition.

6.2.1.3 Vibration monitoring

Drivers of vehicles especially forklifts have no idea when their vibration exposure levels are exceeding recommended or safe limits. It may be necessary to improve awareness of this hazard and offer some proactive method for the driver to assess his own exposure to design and introduce some type of continuous vibration monitoring device on the seat of the vehicle. This device could merely show a colour change indicating when exposure levels are exceeded ie: safe (green), warning (yellow) and danger (red) levels. This system could then allow even the most uneducated driver to assess the vibration dose received by him during a particular shift and allow rest breaks to be taken to reduce exposure dose. This may be linked to an alarm system which can warn when exposure limits are being exceeded. Further work would need to be done to develop this fully.

6.2.2 Procedural and Work Changes

6.2.2.1 Work schedule

Portnet should try to eliminate piece work and task work schedules where a certain work load is allocated to a driver with a time allocation to complete the job where after the driver can go home. This change will help to prevent rushed work, increased driving speeds, shortcuts on rest during the shift and resultant increased vibration exposure. A planned work schedule that is continually monitored would improve the overall vibration exposure characteristics and this type of schedule should be negotiated with the unions concerned to see if any alternative arrangements can be made to improve working conditions, reduce vibration exposure, increase rest and recuperation times and maybe even increase productivity if possible, so achieving a win-win situation for all concerned.

6.2.2.2 Loads carried

Vibration exposure in a twisted or awkward position has been shown to increase the strain the musculo-skeletal system (Wikstrom 1993). This twisting and turning posture is closely linked to the loads carried by forklifts, where the tall loads on the forks force the driver to reverse from one point to another in order to offload the cargo being carried. With an increase in the power and lifting capabilities of the new forklifts this has become more of a problem and increase the amount of time that a driver has to twist his or her body during driving. It would thus be advisable to limit the load heights on the forklifts to a level that allows the driver to move from one point to another in a forward direction without obscuring the drivers vision. This obviously will have an influence on productivity as more trips will have to be undertaken to move a load of cargo, so in future it may be advisable to purchase specially designed forklifts (such as those used in the beverage industry) that have raised driver cabins to allow better views of the terrain ahead even when carrying tall loads.

6.2.2.3 Pre-driving inspections

At Portnet as in many organisations where pool vehicles are used, a system of pre-driving inspections is carried out to ensure the mechanical integrity of the vehicle and the checking of lights, tyres, and fuels and fluids. This does not usually include any checks on the seats of the forklifts and it is recommended that Portnet institute a system of driver responsibility for the checking of the condition of the seat, and adjustment. Many of the forklifts that had adjustable seats had never been adjusted correctly, and in fact some had to be turned using vice grips as they were so corroded and difficult to adjust. Drivers also would need to have access to a scale to weigh themselves so that they can adjust the seat mechanism (vibration attenuation) to suit their particular weight for optimal attenuation.

6.2.2.4 Driving speeds

The speed of a forklift has a direct influence on the amount of vibration produced and transmitted to the driver. It is thus advisable to institute speed control measures and maybe even a fine system for speeding to enforce this requirement. Speed bumps would be counter productive in this instance as the vibration would increase as a forklift traversed this obstacle. However mechanical governor devices are available that can be attached to a vehicle and limit the speed of a vehicle, and these should be considered to ensure that the forklifts are driven at a reasonable speed to reduce overall vibration production and driver exposure.

6.2.2.5 Vehicle purchasing and selection

The buyers of any new equipment have a very important function and responsibility to ensure that the equipment is suitable and economical and is best suited to a particular job. However, this is usually only considered from a production or economic point of view and fails to take into account the people that have to use the equipment, and their health and safety. The direct costs and specifications of new vehicles are often only considered such as prices, fuel economy, engine power and lifting capabilities, and other factors such as ergonomic design, worker comfort and vibration exposure are neglected. These factors will have a large indirect economic influence on any business that are not considered, where the effects and economic implications of factors such as worker absenteeism, ill health, lost time, medical costs and poor labour relations and worker attitudes are not considered. It is thus strongly recommended that these important health and safety aspects are incorporated into any forklift buying policy, where the ergonomic and vibration exposure characteristics of a new vehicle are also considered before a purchasing decision is made. It is also imperative that driver input is obtained to ensure acceptance.

6.2.2.6 Vehicle maintenance

A vehicle maintenance programme often merely entails keeping the vehicle on the road, and does not include any maintenance of the driving seat or vibration attenuation devices built into a vehicle. This results in damaged and uncomfortable seats that cannot be adjusted for vibration attenuation and offering almost no protection for the driver. It is recommended that a full forklift maintenance programme be compiled and implemented that includes the aspects related to driver comfort and vibration protection. All damaged seats need to be repaired and the seat adjustment mechanisms cleaned and lubricated to ensure ease of use.

Vehicle maintenance programmes do not merely keep a vehicle on the road, so that it can be productive, but go a long way in reducing overall vehicle produced vibration such as from the engine, gearbox and tyres, so overall maintenance is also important in this regard.

6.2.3 Training and Education

The success of any programme depends upon its people and the teamwork and effort that goes into achieving the goals of the programme. In a vibration control occupational hygiene programme it is imperative that everyone becomes aware of the problem and each person is trained and motivated to carry out their task or duties that will enable the ultimate goals to be achieved.

In this regard peer education would play a major role in education of the drivers in order to facilitate a change in attitude towards the use of back belts, and to ensure that drivers understand what the role of vibration is in causing back pain. Workers need to be convinced that back belts are not a panacea and other more proven methods of control and prevention are needed.

This does not merely include the drivers of the forklifts, but goes right to the top of the organisation to the CEO who is ultimately responsible for health and safety in any organisation, including Portnet. The line managers, supervisors, buyers, maintenance personnel, medical staff, health and safety/risk officers and drivers should all be involved in the programme and be made aware of their duties and responsibilities in the various important areas of vibration control.

6.2.3.1 Back protection programme

A back protection programme for drivers needs be drafted and implemented that will enable these objectives to be achieved. The programme should incorporate areas that cover the importance of regular exercise of the back and back muscles, the methods of reducing or eliminating twisted or awkward postures, general training and education about the problem of vibration exposure, sources, health effects and control measures and procedures etc. It is imperative that drivers be trained and motivated to carry out proper seat adjustment before driving a forklift and to carry out a pre-driving inspection of the seat surface and vibration attenuation mechanisms. The importance of regular stretching and rest breaks needs to be highlighted and drivers must be convinced that back belts are not the ultimate panacea for this problem, but that it is a multi-faceted complex problem that requires action at all levels of the organisation including the policy making, purchasing, risk control, maintenance and medical functions.

Back Protection Guidelines for drivers can be drafted incorporating all aspects of importance in the protection of the back and musculo-skeletal system and the control measures and standard operating procedures necessary to achieve this. This booklet can then be made widely available and each employee affected should be issued with a copy in his mother tongue, this can then be backed up with training as mentioned above especially for illiterate drivers.

6.2.3.2 Awareness training

Creating awareness regarding a problem and a programme to address the problem is very important for its success, where every individual in the organisation whether directly or indirectly involved is made aware of the goals, objectives and correct actions required to solve the problem. It is thus very necessary to draft a vibration awareness training programme, for all employees that may incorporate handouts, posters, leaflets, booklets, self test questions and overhead transparencies to get the message across. These general information presentations on vibration hazards can then be then can be presented to management and heads of departments that may have an indirect role to play eg: purchasing who will be involved in decision making regarding the purchasing of new forklifts. Peer education would again be very important in changing attitudes and behaviour of the drivers to eliminate bad practices, beliefs and attitudes and encourage each driver to be aware of the problem, the risk factors involved and what must be done in order to reduce the risks of musculo-skeletal injury not only from whole-body vibration exposure, but from all the activities related to the driving occupation.

6.2.4 Driver Related Measures

6.2.4.1 Exercise programme

Exercise programmes run on a daily basis incorporating stretching and limbering exercises could be run before each shift to improve driver back muscle strength. These programmes have been used overseas with some success and lead to a reduction in musculo-skeletal injury (Bracko 1998).

6.2.4.2 Work/Rest cycles

Regular rest breaks are essential for the recovery and resting of the back muscles and other structures, and most professional drivers do not take regular rest breaks from the sitting posture and have prolonged exposure periods that over stress the affected musculo-skeletal structures.

The shifts at Portnet vary from 8 to 12 hours with official rest breaks half way through the shift. Thus drivers do not rest regularly enough if adhering to official rest periods to allow recovery and recuperation of back muscles and structures. This not only increases exposure doses but reduces the exercising and resting of the back muscles, and the diffusion of nutrients into the intervertebral discs necessary for growth and repair.

It has been shown in this study that other rest breaks taken over and above the official mid shift breaks reduce the odds of developing back pain after driving, and this is an important recommendation, Rest breaks should be increased and drivers should be encouraged to dismount from their vehicle and do some basic stretching exercises and walk around whenever possible to allow good circulation of blood and nutrients to the musculo-skeletal structures and back muscles.

6.2.5 Back Belts

The issuing and use of back belts should be regarded with caution as the results of this study show that, although they may reduce the severity of back pain, they also are associated with an increased prevalence in back pain. The use of these belts also can result in a dangerous misconception amongst workers relying solely on the belts for protection against whole-body vibration induced musculo-skeletal disorders and ignoring all the other more important control measures that are needed to holistically control and prevent this hazard.

Thus it is the opinion of the researcher that these devices remain an unproven and unscientific personal protective device and their use should be viewed with caution. Other more proven engineering, administrative and training methods should rather be used to holistically address whole-body vibration hazards.

Problems associated with personal protective equipment such as back belts and the sustainability of their use were indicated by the number of lost and damaged belts that were recorded and the comments by drivers regarding belt quality. A follow up of the belt users after the belts were issued would indicate to what extent the use of these belts is sustainable without ongoing replacement and training and motivation programmes. More effective training and education programmes regarding the reduction and prevention of vibration exposure would rather be recommended than belt training programmes.

6.3 Topics for Further Research

From any research project many questions arise that relate to the problem under investigation, but cannot be included or investigated further for various reasons. It is hoped that other interested researchers can take up some of the issues listed below and increase the knowledge base regarding whole-body vibration exposures and the related aspects.

Intervention studies, or studies investigating engineering or other controls are severely lacking in the musculo-skeletal epidemiological literature especially with regards to whole-body vibration exposure and this area is very necessary if the future solutions to this problem are to be found.

In this study the use of a chronicity tool was found to be a very important and useful method to characterise back pain and this could be developed further to allow and a better understanding of the epidemiological importance of this factor. The method of assessing chronicity appeared simple to use, and generated easily interpreted results, and can be easily adapted by other researchers.

Further research that could be conducted on the use of back belts is to assess the effects of back belts during vibration exposure ie: do they significantly change the vibration exposure profile when they are worn during driving and if so to what extent. Following on from that is the question of what influence they have on vibration as a risk factor for back pain and the long term associated health effects and symptoms. This was not investigated during this study.

Many drivers specifically commented without any prompting on the problem of impotence, and felt it was related to the whole-body vibration exposure. This factor was mentioned very often by drivers without being asked, and is not mentioned anywhere in any of the literature reviewed for this study. The question was not incorporated into the questionnaire, so no specific data was collected other than general comments. However this may be an important area for future research considering the physiological effects of vibration on the circulatory and nervous systems and the importance these systems play in sexual function.

Another observation that was made by the researcher that may be an area of future research is the selling of special "muti" preparations by traditional healers prepared and prescribed especially for back pain every Friday on payday at the port. The research questions that arise would be what these preparations are (ingredients) and active ingredients, and how effective they are in relieving pain especially back pain.

REFERENCES

REFERENCES.

American Conference of Governmental Industrial Hygienists: Threshold Limit Values (TLV's) and Biological Exposure Indices (BEI's). ACGIH Worldwide, 1995-1998.

A.I.H.A. 1999. American Industrial Hygiene Association Position Statement on Ergonomics. [On-line] Available from URL:http://www.aiha.org/papers/ergo/html. [Accessed 11-03-99].

Anonymous. Study shows back supports reduce back injuries by a Third. National Safety. 1997, March/April edition.

ANSI S3.18 (and ASA 38): Guide for the Evaluation of Human Exposure to Whole-Body Vibration. American National Standards Institute (and Acoustical Society of America), New York, NY, 1979.

Baichoo P. (baichoo@ilo.org) 27-05-99. RE: Back belts. E-mail to Joubert D. (Darren@julian.mantec.ac.za).

Blosser F. 17 March 1998. NIOSH Funded Research. Occupational and Environmental Medicine Mailing List [On-line] Available from URL:occ-env-med-l@dudley.mc.duke.edu [Accessed 20-03-98].

Bogadi-sare A. The effects of whole-body vibration: an unrecognised problem. *Arh Hig Rada Toksikol.* 1993 Sep, 44(3) : 269-79.

Bongers P and Boshuizen H. Back Disorders and Whole-Body Vibration at Work. *Offsetdrukkerij Kanters bv, Alblasserdam*, University of Amsterdam, 1990.

Bongers P, Boshuizen H and Hulshof C. Self reported back pain in drivers of wheelloaders. *Offsetdrukkerij Kanters bv, Alblasserdam*, University of Amsterdam, 1990, 207-220.

Boshuizen H, Bongers P and Hulshof C. Whole-body vibration and back disorders; a meta analysis. *Offsetdrukkerij Kanters bv, Alblasserdam*, University of Amsterdam, 1990, 223-250.

Bovenzi M and Hulshof C. An updated review of epidemiological studies on the relationship between exposure to whole-body vibration and low back Pain. Journal of Sound and Vibration. 1998, 215: 595 - 611.

Bracko M. Fit for Duty: workers at Chinook industrial warm up to the idea of pre-work exercise. Canadian Occupational Safety. May/June 1998, 36 (3):20-23.

Brendstrup T and Biering-Sorensen F. Effect of fork-lift truck driving on low back trouble. Scand.J.Work Enviro Health 1987, 13:445-452.

British Standards Institution. Measurement and Evaluation of Human exposure to Whole-Body Mechanical Vibration and Repeated Shock. British Standards Guide: BS 6841: 1987.

Brink H.I. Fundamentals of Research Methodology for Health Care Professionals 1st Ed. Juta & Co. 1996.

Brown L. Abdominal Belts: essential support or industrial crippler? Safety Management. 1996 Feb.

Bruel and Kjaer, Vibration Handbook, Denmark, 1985.

Burdorf A. (Burdorf@mgz.fgg.eur.nl) 23-04-99. RE: Back belt use against WBV. E-mail to Joubert D. (Darren@julian.mantec.ac.za).

Burdorf A. (Burdorf@mgz.fgg.eur.nl) 02-06-98. RE: Article on seat suspension. E-mail to Joubert D. (Darren@julian.mantec.ac.za).

Burdorf A and Swuste P. The effect of seat suspension on exposure to whole-body vibration of professional drivers. Ann.Occup.Hyg. 1993, 37(1): 45-55.

Burgess-Limerick R. 1996. Case study: Ergonomics issues involving forklifts. [On-line] Available from URL: http://www.uq.edu.au/~hmrburge. [Accessed 09-96].

Canadian Centre for Occupational Health and Safety. 1997. Canadian Ministry of Labour Alert: weightlifting or lumbar support belts in manual materials handling work. [On-line] Available from URL: http://www.ccohs.ca/ccohs/alerts/alert90.txt.. [Accessed 31-07-97].

Canavan T. 1999. Product Review: Kevco/Stubbs Kidney Belt. [On-line] Motorcycle Online, California, USA. Available from:URL:http://cgi.motorcycle.com/mo/mcdirt/stubbs.html. [Accessed 21-04-99].

Cirello, V.M. and Snook, S.H. The effect of back belts on lumbar muscle fatigue. Spine. 1995, 20 (11): 1271-1278.

Coerman R. Mechanical Vibrations. Occupational Safety and Health Series. 1968, 21: 17-41.

Committee on Scientific Writing, RMIT Manual on Scientific Writing. Victoria:. TAFE Publications, 1993.

Congleton J, Amendola A, Horsford W, McCoy M, Reddell C, Sherwood, and Wilson K. Brief Summary of Lifting Belt Research conducted at Texas A & M University. Ergonomics of Manual Work. Taylor and Francis, 1993: 139.

Council of the European Union. Amended proposal for a council directive on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents - individual directive in relation to article 16 of the directive : 89/311/EEC, Brussels. Official Journal of the European Communities. 1994, 94/C 230/3, No C230/3-29.

Day RA. How to Write and Publish a Scientific Paper. 4th Ed. Great Britain:. Cambridge University Press, 1996.

De Klerk J. South African Institute of Materials Handling (Personal communication) 31-05-00. RE: Forklift drivers numbers in South Africa. Telephonic Communication to Joubert D.

Department of Labour. Occupational Health and Safety Act. Act 85 of 1993. Government Gazette, Pretoria, South Africa, 1993.

Dinardi S.R. The Occupational Environment - its Evaluation and Control. AIHA Press, American Industrial Hygiene Association, 1997: 468.

Dorlands Pocket Medical Dictionary. 24th Ed. 1989. Philadelphia, PA. W.B. Saunders Company.

Dupuis H. Medical and occupational pre-conditions for vibration-induced spinal disorders: occupational disease No: 2110 in Germany. Int Arch Occup Environ Health 1994, 66: 303-308.

Etheridge D. Back support belts: Effectiveness in the prevention of occupational back injuries. National Safety and Occupational Hygiene. 1996, LV1(5): 32.

Farmer R and Miller D. Lecture Notes on Epidemiology and Community Medicine. London: Blackwell Scientific Publications, 1983.

Futatsuka M, Maeda S, Inaoka T, Nagano M, Shono M and Miyakita T. Whole-body vibration and health effects in the agricultural machinery drivers. Industrial Health. 1998, 36:127-132.

Gardner L, Rossignol M, Mortimer B and Koes B. Analysis of epidemiological studies of back belts. JOEL. 1998 Feb, 40 (2): 101-103.

Goelzer B. (Goelzerb@who.ch) 20-05-99. RE: WHO position on back belts. E-mail to Joubert D. (Darren@julian.mantec.ac.za).

Government Gazette Republic of South Africa, Department of Labour. Occupational Health and Safety Act (Act 85 of 1993), 1993.

Grandjean E. Fitting the Task to the Man: A Textbook of Occupational Ergonomics 4th Ed. Taylor and Francis, 1988.

Griffin M.J. Predicting the hazards of whole-body vibration: considerations of a standard. Industrial Health. 1998, 36:83-91.

Harman, E.A., Rosenstein, R.M., Frykman, P.N., and Nigro, G.A. Effects of a belt on intra-abdominal pressure during weight lifting. Med. Sci. Sports Exercise. 1989, 2 (12): 186 - 190.

Health and Safety Executive. 1997. Press release: In the Driving Seat. [On-line], United Kingdom. Available from URL: http://www.open.gov.uk/hse/press/e978.htm [Accessed 29-07-98].

Hendrikse J. Why truck drivers need good seats: driver health. South African Transport, 1996 Jun, 28(319): 24-25.

Hendrikse J. Vibration and human task performance. Paper read at Noise and Vibration Conference 93, 1993 Sep, Pretoria.

Hill AB. The environment and disease: Association or Causation.? Proceedings of the Royal Society: section of occupational medicine. 1965, 58:295-300.

Hubbuch SM. Writing Research Papers across the Curriculum. New York: CBS College Publishing, 1985.

Hulshof C and van Zantern BV. Whole-body vibration and low back pain: a review of epidemiological studies. Int Arch Occup Environ Health. 1987, 50 :205-220.

Hunter, G.R., McGuirk, J., Mitrano N., Pearman, P. Thomas, B., and Arrington, R. The effects of a weight training belt on blood pressure during Exercise. J. Appl. Sport Sci. Res. 1989, 3 (1): 13-19.

Isaac S and Michael W. Handbook in research and evaluation. 2nd Ed, California USA: Edits Publishers, 1990.

International Labour Organisation.. Encyclopaedia of Occupational Health and Safety. 4th Ed. ILO Geneva, Switzerland, 1998: 28.1 - 28.39.

Ishatake T, Kano. M, Miyazaki Y, Ando H., Tsutsumi A. and Matoba T. Whole-body vibration suppresses gastric motility in healthy men. Industrial Health 1998, 36: 93 - 97.

Ishikawa F. Development of vibration protection seats for agricultural machinery. Industrial Health. 1998, 36:133-139.

ISO 2631/1:1997(E). Mechanical Vibration and Shock-Evaluation of Human Exposure to Whole-Body Vibration. Part I: General Requirements. International Standardisation Organisation, Geneva, 1997.

ISO 2631/1:1985. Mechanical Vibration and Shock-Evaluation of Human Exposure to Whole-Body Vibration. Part I: General Requirements. International Standardisation Organisation, Geneva, 1985.

Jensen MP, Karoly P and Braver S. The measurement of clinical pain intensity: a comparison of six methods. Pain. 1986, 27:117-126.

Karwowski W and Marras W. The Occupational Ergonomics Handbook. USA: CRC Press, 1998.

Kevco/Stubbs.1999.The Press [On-line], California, USA. Available from URL:http://www.kevco-stubbs.com/press.html. [Accessed 16-04-99].

Kramer J. *Biomechanische Veranderungen im Lumbalen Bewegungssegment.* Hippokrates, Stuttgart, 1973.

Kraus JF, Brown KA, McArthur DL, Peek-Asa C, Samaniego L, Kraus C, Zhou L. Reduction of acute low back injuries by use of back supports. International Journal of Occupational and Environmental Health. 1996, 2(3).

Kumar S. The effect of sustained spinal loading on intra-abdominal pressure and EMG characteristics of trunk muscles. Ergonomics. 1997, 40(12): 1312-34.

Kuorinka I, Jonsson B, Kilborn A, Vinterburg H, Biering-Sorenson F, Andersson G and Jorgensen K. Standardised Nordic questionnaires for the analysis of musculoskeletal symptoms. Appl. Ergonomics 1987, 18.3: 233-237.

Lander, J.E., Hundley, J.R., and Simonton, R.L. The effectiveness of weight belts during multiple repetitions of the squat exercise. Med. Sci. Sports Exercise. 1992, 24 (5): 603-609.

Leboeuf-Yde C and Lauritsen J. The prevalence of low back pain in the literature: A structured review of 26 Nordic studies from 1954 to 1993. Spine. 1995 Nov, 20(19): 2112-18 .

Leedy PD. Practical Research: Planning and Design. 5th Ed. New York: Macmillan Publishing, 1993.

Liberty Mutual Research Centre.1999.Firms meter evaluates whole-body vibration. [On-line], Boston, Mass., USA. Available from URL:http://www.libertymutual.com/research/news/releases/press_a.html. [Accessed 10-03-99].

Liberty Mutual Research Centre.1999.The high cost of back pain.[On-line], Boston, Mass., USA. Available from URL:http://www.libertymutual.com/research/news/releases/press_x.html. [Accessed 10-03-99].

Lilienfeld D and Stolley P. Foundations of Epidemiology. 3rd Ed. New York : Oxford University Press, 1994.

Malchaire J, Piette A and Mullier I. Vibration on forklift trucks. Ann.Occup.Hyg. 1996, 40(1):79-91.

McCoy, M.A., Congleton, J.J., Jognston, W.L., and Jiang, B.C. The role of lifting belts in manual lifting. Int.J. Ind. Ergonomics. 1988, 2: 259-266.

McGill S. Should industrial workers wear abdominal belts? Prescription based on the recent literature. Int.J. Ind. Ergonomics . 1999, (23):633-636.

McGill S. (McGill@healthy.uwaterloo.ca) 21-04-99. RE: Back belt article. E-mail to Joubert D. (Darren@julian.mantec.ac.za).

McGill S.M., Seguin, J.P., and Bennett, G. Passive stiffness of the lumbar torso in flexion, extension, lateral bend and axial twist: The effect of belt wearing and breath holding. Spine. 1994, 19(6): 696-704.

McGill S. Abdominal belts in industry: a position paper on their assets, liabilities and use. Am.Ind.Hyg.Assoc.J. 1993, 54(12):752-754.

McGill S., Norman, R.W., and Sharratt, M.T. The effect of an abdominal belt on trunk muscle activity and intra-abdominal pressure during squat lifts. Ergonomics. 1990, 33(2): 147-160.

McGill, S.M. and Norman, R.W. Reassessment of the role of intra-abdominal pressure in spinal compression. Ergonomics. 1987, 30 (11): 1565-1588.

Mclain RF and Weinstein JN. Effects of whole-body vibration on dorsal root ganglion neurons. Changes in neuronal nuclei. Spine. 1994 Jul, 19(13): 1455-61.

McMichael A.J. Standardised mortality ratios and the "Healthy Worker Effect": scratching beneath the surface. J. Occup. Med, 1976, 18: 165 - 168 .

Melville S and Goddard W. Research Methodology: An Introduction for Science and Engineering Students. Cape Town: Juta & Co., 1996.

Mitchell, L.V., Lawler, F.H., Bowen, D., Mote, W., Asundi, P. and Purswell, J. Effectiveness and cost-effectiveness of employer-issued back belts in areas of high risk for back injury. J. Occup. Med. 1994, 36(1):90-94.

Musch FH. *Lumbalsyndrom bei Erdbaumaschinenfahrern mit Langerjariger Ganzkorpervibrationsbelastung.* Vibration At Work. 1990 : 64-67.

Nachemson, A.L., Andersson, G.B.J., and Schultz, A.B. Valsalava manoeuvre biomechanics: Effects on lumbar trunk loads of elevated intra-abdominal pressures. Spine. 1986, 11(5): 476-479.

Nachemson A and Elfstrom G. Intravital dynamic pressure measurements in lumbar discs. Scandinavian Journal of Rehabilitation Medicine. 1970, Suppl. 1.

Naval Aerospace Medical Institute. 1991. Vibration. [On-line] Virtual Naval Hospital, U.S.A. Available from URL: http://www.vnh.org/fsmanual/02/04vibration.html. [Accessed 10-03-99].

N.I.O.S.H. 1999. National Occupational Research Agenda [On-line] Cincinnati, USA. Available from URL:http://www.cdc.gov/NIOSH/norhmpg.html. [Accessed 12-11-99].

N.I.O.S.H. 1997. Fact Sheet-Back Belts [On-line] Cincinnati, USA. Available from URL:http://www.cdc.gov/NIOSH/backfs.html. [Accessed 21-04-99].

N.I.O.S.H: Back Belt Working Group, National Institute for Occupational Safety and Health, Cincinnati, 1994.

N.I.O.S.H: Work Practices Guide for Manual Lifting. National Institute for Occupational Safety and Health, Cincinnati, 1981.

Notter LF. Essentials of Nursing Research. 2nd Ed. London: Tavistock Publications, 1986.

Pittsburg Research Laboratory, Mining Health and Safety Research. 1997. Human Factors Design Recommendations for Underground Mobile Mining Equipment. [On-line] Available from URL:http://www.cdc.gov/niosh/pit/hfg_seat1.html. [Accessed 23-04-99].

Plog BA. Fundamentals of Industrial Hygiene. 4th Revised Ed. Chicago National Safety Council, 1996: 29.

Plog BA. Fundamentals of Industrial Hygiene. 3rd Revised Ed. Chicago National Safety Council, 1988: 26.

Pope MH and Novotny JE. Spinal biomechanics. J.Biomech.Eng. 1993 Nov, 115(4b): 569-74.

Pope M, Wilder D, Jorneus L, Broman H, Svensson M and Andersson G. The responses of the seated human to sinusoidal vibration and impact. J.Biomech.Eng.. 1987, 109 : 279-284.

Pope M, Wilder D, Jorneus L, Broman H, Svensson M and Andersson G. The responses of the seated human to sinusoidal vibration and impact. J. Biomech. Eng. 1987, 109 : 279-284.

Rafacz, W. and McGill, S.M. Abdominal belts increase diastolic blood pressure. J. Occup. Environ. Med. 1996, 38(9): 925-927.

Rassmussen G. Technical Review: Human Body Vibration. Bruel and Kjaer, Denmark, No.1, 1987.

Reddell, C.R., Congleton, J.J., Huchinson, R.D., and Mongomery J.F. An evaluation of a weightlifting belt and back injury prevention training class for airline baggage handlers. Appl. Ergonomics. 1992, 23(5): 319-329.

Reyna, J.R., Leggett, S.H., Kenney, K., Holmes, B. and Mooney, V. The effect of lumbar belts on isolated lumbar muscle. Spine. 1995, 20(1): 68-73.

Riihimaki H, Tola S, Videman T, and Hanninen K. Low Back Pain and Occupation. A cross-sectional questionnaire study of men in machine operating, dynamic physical work and sedentary work. Spine 1989, 14:204-209.

Rosenstock L. 1997. Report of Written Testimony from the Director National Institute for Occupational Safety and Health to the Sub-Committee on Workforce Protection [On-line], Cincinnati, USA. Available from URL:http://www.cdc.gov.niosh/nioshfin.html. [Accessed 21-04-1999].

Rys M and Konz S. Lifting belts? Ergonomics of Manual Work. Taylor and Francis, 1993: 141.

S.A.B.S. 0259:1990. General Requirements for the Competence of Calibration and Testing Laboratories. Code of Practice. South African Bureau of Standards, 1990.

Salie F.1998. Personal communication to Joubert D.10-09-98.Global Ergonomics Conference, Cape-Town, South Africa.

SAS Institute Incorporated. 1990. SAS/STAT (version 6) [Computer Programme] Cary NC USA.

Schilling R and Andersson N. Occupational epidemiology in developing countries. J.Occup Health and Safety - Aus Nz. 1986, 2(6):468-478.

Schoeman J and Schroder H. Occupational Hygiene. 2nd Ed. Juta and Co., 1994: 246.

Scuria-Fontana C. Fighting vibration with vibration. Mechanical Engineering. 1994 Sep, 116(9) : 38.

Seroussi RE, Wilder DG, and Pope MH. Trunk muscle electro-myography and whole-body vibration J.Biomech.Eng. 1989, 22: 219 - 229.

Soloman E.P. and Davis P.W. Human Anatomy and Physiology. CBS College Publishing; 1983: 167.

Stein G.J. A drivers seat with active suspension of electro-pneumatic type. Journal of Vibration and Acoustics. 1997, 119:230-235.

Summers A. Establishing a pre-employment screening programme to reduce back injuries in bus drivers. In Ergonomics and Human Environments: proceedings of the annual conference of the Ergonomics Society of Australia held in Coolum, QLD. 1991, 27:247-254.

Thalheimer E. Practical approach to measurement and evaluation of exposure to whole-body vibration in the workplace. Seminars in Perinatology. 1996 Feb, 20(1):77-89.

Thompson L, Davidson H and Hirsh D. Attitudes and back belts in the workplace. Work. 1994, 4(1):22-27.

Van der Merwe H. (polimed.merwe@cyberserv.co.za) 23-02-1997. Back Support Belts. Email to Joubert D (darren@julian.mantec.ac.za).

Van Poppel M, Koes B, van der Ploeg T, Smid T. and Bouter L. Lumbar supports and education for prevention of low back pain in industry. JAMA, June, 1998: 279 (22).

Videman T, Nurminen M and Troup J.D. Lumbar spinal pathology in cadaveric material in relation to history of back pain, occupation and physical loading. Spine 1990, 15: 728 - 740.

Visser N. Handbook for Writers of Essays and Theses. 2nd Ed. Cape Town: Maskew Miller, 1993.

Walsh, N.E. and Schwartz, R.K. The influence of prophylactic orthoses on abdominal strength and low back injury in the workplace. Am. J. Phys. Med. Rehab. 1990, 69(5): 254-250.

Wan Y and Schimmels J.M. Optimal seat suspension design based on minimum "simulated subjective response". J. Biomech. Eng. 1997, 119:409-416.

Wasserman D.E, Wilder D.G, Pope M. H, Magnusson M, Aleksiev A.R, and Wasserman J.F. Whole-body vibration exposures and occupational work hardening. JOEM. 1997, 39(5):403-407.

Wikstrom B.O. Effects from twisted postures and whole-body vibration during driving. International Journal of Industrial Ergonomics 1993, (12): 61 - 75.

Wilder D.G, Pope M.H and Magnusson M. Mechanical stress reduction during seated jolt/vibration exposure. Seminars in Paranatology. 1996, 20(1):54-60.

Workmens Compensation Board of British Columbia, Canada. 1995. Ergonomics Commentary: Back Belts may not Prevent Injuries at Work. [On-line] Available from http://www.wcb.bc.ca/resmat/pubs/ergcomm/ergcomm1.htm. [Accessed 11-03-99].

World Health Organisation. 1994. Epi-Info. (DOS version 6) [Computer Programme Shareware On-line],Geneva, Switzerland. Available from URL:http://www.cdc.gov/epo/epi/epiinfo.htm.

World Health Organisation. Epidemiology of occupational hygiene. European Series No: 20, Geneva, Switzerland,1986.

APPENDICES

APPENDIX A

APPENDIX A: Definitions.

A

Acceleration: Any gradual speeding up of a process. The time rate of change of velocity.

Accelerometer: A sensor who's output is proportional to acceleration. Also known as a transducer.

American Conference of Governmental Industrial Hygienists (ACGIH): Founded in 1938, this professional organisation of government and university industrial hygienists had a membership of 5400 in 1996. Many of the ACGIH technical committee publications eg: threshold limit values [TLVs®] are recognised worldwide as authoritative sources.

American Industrial Hygiene Association (AIHA): Founded in 1939, this professional organisation of industrial hygienists from the private and public sectors had a membership of more than 13,000 in 1996. AIHA is recognised for its technical committee publications, its proactive role in governmental affairs, and for promoting the profession of industrial hygiene.

American National Standards Institution (ANSI): A voluntary membership organisation that develops consensus standards. Headquarters are in New York, N.Y.

Amplitude: The measurement of energy or movement in a vibrating object, which helps define the severity of the vibration.

Anthropometry: The science of measurement of the body's mass, size, shape, and inertial properties.

Attenuation: Any means of dissipating vibration energy within a vibrating system.

Attitudes: An attitude is a learned orientation or disposition towards an object or situation which provides a tendency to respond favourably or unfavourably to the object or situation. The response to an object or situation results from an evaluation which expresses the persons attitude towards it. These evaluations are expressed in terms of liking/disliking, favouring/not favouring, pro/anti, and positive/negative. A given attitude is often a summary of evaluations made of different aspects of the attitude object.

Back or Kidney Belt: These are devices that vary in design, but are generally manufactured from layers of elasticised material, with Velcro ends for attachment and adjustment, and may or may not have vertical support stays for additional support. The belts are usually thicker at the back and narrower at the front and are stretched around the persons lumbar region and waist area and fastened by Velcro at the front or side. This then is thought to offer support to the lumbar area, by increasing the intra-abdominal pressure and supporting the spinal column, and surrounding organs. They are also known as lifting belts or abdominal belts.

Back pain: Any acute or chronic pain, ache or stiffness experienced by the worker in any part of the back, including the shoulder area.

Beliefs: A belief is a statement about the attributes or characteristics of an object, person, the world etc, that an individual thinks is true. A person may, therefore believe that the back belts are effective in preventing or reducing back pain. Such a belief may in turn lead to an attitude about a particular object.

Broad-band: A band with a wide rage of frequencies.

C

Cadaveric Material: Material obtained from a dead human body preserved for anatomical study.

Calibration: Establishment of a relationship between various calibration standards and the measurements of them obtained by a measurement system, or portions thereof. Determination of the accuracy of an instrument, usually by measurement of its variation from a standard to ascertain necessary correction factors.

Calibration Standard: A standard used to quantitate the relationship between the output of a sensor and a property to be measured. Calibration standards should be traceable to a standard reference material (SRM), certified reference material (CRM), or a primary standard.

Charge Amplifier: An amplifier whose output voltage is proportional to the output charge from a piezoelectric sensor or transducer. Has the advantage that voltage output is not affected by length of connective cable.

Chronic effect: Disease symptom or process of long duration, usually frequent in occurrence, and almost always debilitating.

Cohort study: A group of research subjects who share some property at a given time, followed up over the duration of a research study

Confidence interval: An interval that has a designated probability (the confidence coefficient) of including some defined parameter of the population.

Control: One of four primary responsibilities of the occupational hygienist. It is the culmination of the effort in addressing the primary objective of the occupational hygienist: providing a healthful work environment. Current occupational hygiene practice recognises a hierarchy of controls; in priority order, these are engineering controls, work practices, administrative controls, and as a last resort use of personal protective equipment.

Criteria for Fatigue Decreased Proficiency (FDP): Boundaries that represent the ability of a person to work at tasks under vibration exposure without the vibration interfering with the worker's ability to perform.

Cumulative dose: Total dose resulting from repeated exposures.

D

Damping: The action of frictional or dissipative forces on a dynamic vibrating system causing the system to lose energy and reduce the amplitude of movement, by dissipating vibration energy.

Displacement: 1. The linear distance from the initial to the final position of an object moved from one place to another, regardless of length of path followed. 2. The distance of an oscillating particle from its equilibrium position.

Dose-response curve: 1. Graphic representation relation biologic response to concentration of contaminant and time of exposure. By multiplying these factors, dose is determined. 2. A mathematical relationship between the dose administered or received and the incidence of adverse health effects in the exposed population; toxicity values are derived from this relationship.

Dose-Response Relationship: A relationship in which a change in amount, intensity, or duration of exposure is associated with a change-either an increase or a decrease in risk of a specified outcome or greater or lesser biological effects (ie: responses).

E

Electromyogram (EMG): The detected electrical signal of a muscle contraction.

Electromyography: The study of the electrical signal associated with a muscle contraction.

Engineering controls: Process change, substitution, isolation, ventilation, source modification.

Epidemiology: The science that deals with the distribution and risk factors of disease in a population.

Ergonomics: The application of human biological sciences with the engineering sciences to achieve optimum mutual adjustment of people and their work, the benefits measured in terms of human efficiency and well-being.

Evaluation: One of four primary responsibilities of the occupational hygienist. The examination and judgement of the amount, degree, significance, worth, or condition of something. Evaluation perhaps uses more "art" in its implementation and than any of the other occupational hygiene responsibilities.

F

Frequency (F): The time rate of repetition of a periodic phenomena. The frequency is the reciprocal of the period and is sometimes called pitch.

H

Hawthorne Effect: A tendency for employees to do the job in a non-routine manner while being observed.

Healthy worker effect: A phenomenon observed initially in studies of occupational diseases; workers usually exhibit lower overall death rates than the general population because severely ill and disabled are ordinarily excluded from or leave employment because of illness.

Hertz (Hz): Unit of frequency equal to one cycle per second.

I

Intervention study: An epidemiological investigation designed to test a hypothesised cause-effect relationship by modifying a supposed causal factor or introducing a new control measure or factor into a sample population.

L

Lower back pain: Any acute or chronic pain, ache or stiffness experienced by the worker in the lower part or lumbar region of the back, lumbago or chronic recurrent discomfort in the lower back/lumbar area excluding sciatic pain radiating into the legs.

Lumbar Spine: The section of the lower spinal column or vertebral column immediately above the sacrum. Located in the small of the back and consisting of five large lumbar vertebrae, it is a highly stressed area in work situations and supporting the body structures.

M

Mass loading: The situation in which an accelerometer that is too heavy will weigh down the surface and give inaccurate results. To avoid mass loading, the general rule is that the accelerometer's mass should be no more than one-tenth (1/10) of the effective mass of the surface to which it is mounted.

N

National Institute for Occupational Safety and Health (NIOSH): Established by the Occupational Safety and Health Act of 1970, NIOSH is part of the Centres for Disease Control and Prevention within the U.S. Department of Health and Human Services. NIOSH, based in Cincinnati, Ohio, traces its origins to 1914 when the U.S. Public Health Service organised a division of Industrial Hygiene and Sanitation. NIOSH's responsibilities include research and recommending occupational health and safety standards.

National Safety Council (NSC): The NSC is a nonprofit, international public service organisation dedicated to improving the safety, health, and well-being of populations throughout the world. Total membership exceeds 18500. Headquarters are in Itasca, Ill.

O

Occupational exposure limit (OEL): A health-based workplace standard to protect workers from adverse exposure (e.g., PELs, TLVs®, RELs, WEELs, etc.)

Opinions: An opinion is a verbalised attitude, an in this case it is hoped that the questionnaire responses would allow this expressing of "attitude" and therefore the opinion of the drivers on various aspects of the belts and their use.

P

Periodic vibration: Vibration is considered periodic if the motion of a particle repeats itself considerably over time.

Personal Protective Equipment (PPE): Equipment (e.g., gloves, eye protection, respirators) whose use by exposed workers is intended to protect individuals from workplace hazards.

R

Random error: Variations in measurements that are random in nature and individually not predictable. The cause of random error are presumed to be indeterminate or non-assignable.

Random vibration: A varying force acting on a mechanical system which may be considered to be the sum of a large number of irregularly timed small shocks; induced typically by aerodynamic turbulence, airborne noise from rocket jets, and transportation over road surfaces.

Recognition: One of four primary responsibilities of the industrial hygienist. The line separating "anticipation" and "recognition" is not always a clear one. Some have distinguished them on the basis of whether the situation being examined actually exists. If it is still in a conceptual phase, the process being applied is considered to be "anticipation". Then it is assumed that, in the recognition phase, the facility exists. This is a somewhat arbitrary distinction; anticipation of hazards can and does occur with existing facilities and recognition of hazards can take place when the facility is in a planning stage.

Reduced comfort (RC) resonance: The boundaries concerned with preservation of comfort during vibration exposure.

Representative sample: A sample taken in such a way that it is representative of a lot or population. A representative sample is commonly achieved by selecting a completely random sample.

Resonance: A significant rise in the response to vibration towards a sharp peak at the resonant frequency of a body causing an increase in apparent expected accelerations measured at these frequencies.

Risk: Probability and magnitude of harm. For exposures to chemicals, risk is a function of both exposure and toxicity.

Risk factor: Characteristic (e.g., race, sex, age, obesity) or variable (e.g., smoking, occupational exposure level) associated with increased probability of a toxic or adverse health effect.

Root-mean-square (rms): The square root of the arithmetic mean of the squares of a set of values.

S

Shock: A pulse or transient motion or force lasting thousands to tenths of a second that is capable of exciting mechanical resonances.

Stratified sample: A sample consisting of various portions that have been obtained from identified subparts or subcategories (strata) of the total lot, or population. Within each category or strata, the samples may be taken randomly. The objective of taking stratifies samples is to reduce sampling error or to control confounding. The idea of identifying the subcategories or strata is based on knowledge of suspicion of (or protection against) differences existing among the strata for the characteristics of concern. The identification of the strata is based on knowledge of the structure of the population, which is known or suspected to have different relationships with the characteristic of the population under study. Opinion polls or surveys use stratified sampling to ensure proportional representation of the various strata (e.g., geographic location, age group, sex etc.).

T

Tendon: Fibrous tissue, similar to a ligament, that attaches muscle to bone.

Transducer: See Accelerometer

V

Validated sampling and analysis method: A method that has met critical accuracy requirements when tested throughout the working range.

Velocity: A vector quantity that specifies time rate of change of displacement or movement.

Vibration-induced damage: Bodily damage caused by excessive exposure to vibration.

W

Whole-body vibration: The exposure of the entire body to workplace vibrations. Whole-body vibration can cause both physiological and psychological effects ranging from fatigue and irritation to motion sickness (kinetosis) and to tissue damage.

Work-Related Musculoskeletal Disorders (WMSDs): The specific term "work-related musculoskeletal disorders" refers to: 1) musculoskeletal disorders to which the work environment and the performance of work contribute significantly; or 2) musculoskeletal disorders that are made worse or longer lasting by work conditions. These workplace risk factors, along with personal characteristics (e.g., physical limitations or existing health problems) and societal factors, are thought to contribute to the development of WMSDs.

APPENDIX B

APPENDIX B: Electronic Media Consulted.

1) **Medline** (National Library of Medicine, United States of America),

2) **NIOSHTIC** (National Institute for Occupational Safety and Health, United States of America),

3) **Whole-body Vibration Database** (National Institute for Working Life, Sweden),

4) **JAMA** (On-line Journal of the American Medical Association),

5) **On-line Scandinavian Journal of Work, Environment and Health,**

6) **New England Journal of Medicine On-line,**

7) and local databases like **Sabinet** on-line.

APPENDIX C

APPENDIX C: Letter of Request to Portnet, Union and Management Co-operation Letters.

City Terminals
6th Floor
Durmarine
Port of Durban
Durban
4001

Dear Sir,

REQUEST FOR PERMISSION TO CONDUCT RESEARCH:

TITLE: AN EVALUATION OF RISK FACTORS ASSOCIATED WITH LOWER BACK PAIN IN FORKLIFT DRIVERS SUBJECTED TO WHOLE BODY VIBRATION EXPOSURE, IN ORDER TO ESTABLISH THE EFFECTIVENESS OF THE USE OF BACK/KIDNEY BELTS IN REDUCING THE PREVALENCE AND SEVERITY OF LOWER BACK PAIN

I would like to request written letters of collaboration/co-operation from Management as well as the relevant workers unions, to conduct the above mentioned research towards a Masters Degree at Portnet, Durban. (See attached protocol, annexure A)

In addition to the letters referred to above, the researcher will obtain individual permission from all participants in the study by means of the administration of an informed consent form. In order to measure the health outcome (effectiveness) of the intervention, it will be necessary for Portnet to implement the most economically viable options that are recommended as a result of the study. It is understood that the research will be funded externally and the only cost to Portnet will be the implementation of interventions.

This research is subject to receiving approval from Portnet Management and Workers, as well as The University of Cape Town, Faculty of Medicine, Ethics and Higher Degrees committees.

Please feel free to contact me should you require any further information.

Yours Sincerely,

____

Darren Joubert.

Researcher

261 PORTNET

Aan / To: Operations Managers
Berth Managers
Assistant Berth Managers
CITY TERMINALS
PORTNET, PORT OF DURBAN

Van / From: Sarel Broodryk
Manager: City Terminals
Suite 600
Durmarine Building
PORT OF DURBAN

Verwysing / Reference:

Telefoon / Telephone: 361-8656
Faks / Fax: 361-8490
Teleks / Telex:

Datum / Date: 20/10/97

REQUEST FOR CO-OPERATION OF INVESTIGATION INTO ERGONOMIC STUDY ON FORKLIFTS

The Risk Department of City Terminals is undertaking a project with regard to investigating the impact of vibration of forklifts on drivers.

As part of study, a questionnaire is to be completed to obtain the raw data for future analysis into the problem.

Our consultant, Mr Darren Joubert and associates will be visiting all terminals from Tuesday 21 October during work hours, to obtain verbal, as well as written feedback from forklift drivers.

You are kindly requested to allow your affected staff to provide Mr Darren Joubert with the relevant information.

Your co-operation in this important study is crucial to the benefit of our employees.

If there are any queries regarding the above, please do not hesitate to contact Stephanie Samuels from the Risk Department on tel. no. 361-8656.

Kind regards

Signed

S.W. BROODRYK
MANAGER: CITY TERMINALS
PORT OF DURBAN

PORTNET

Faculty of Medicine Higher Degrees Sub - Committee
Cape Town
Barnard Fuller Bldg.
Anzio Road
Observatory
7925

Streek / Region: Durban

Verwysing / Reference: CTR 2 / 31

Straatadres / Street address: Bayhead Road
Pier No . 1

Posbus / PO Box	1027	Faks / Stad / City	Durban	Datum / Kode / Code	4 000
Telefoon / Telephone	361 - 6483	Faks / Fax	361 - 6470	Teleks / Telex	Datum / Date 30/07/98

COOPERATION IN RESEARCH STUDY ON BACK PAIN CAUSED BY WHOLE BODY VIBRATION IN LIFTING MACHINES

Dear Sir / Madam

This letter serves to confirm that Portnet Management and Labour of Combi Terminal and its employees are willing to co-operate in the above-mentioned study being conducted at Portnet : Combi Terminal - Port of Durban by Mr. Darren Joubert .

We trust that our co-operation and assistance in the study will help to find solutions to the problem .

Yours faithfully

Signed

I Moodley
Acting Manager : Combi Terminal

E Cronje
Human Resources Manager

Signed

S du Plessis
Risk Control Officer

T Mfathuzo
Representing SARHWU

Signed

BW Caswell
Representing TWU

MS Naidoo
Representing TATU

Signed

RN Jamieson
Representing MIWU

PORTNET

Faculty of Medicine Higher Degrees Sub - Committee
University of Natal
Medical School
PO Box 17039
Congella
4013

Streek / Region

Verwysing / Reference

Straatadres / Street address: Suite 205, Ocean Terminal, Durban

Posbus / PO Box: 1027 | Stad / City: Durban | Kode / Code: 4000

Telefoon / Telephone: 361-8853 | Faks / Fax: 361-8906 | Teleks / Telex: | Datum / Date: 18/02/97

RE : CO-OPERATION IN RESEARCH STUDY ON BACK PAIN CAUSED BY WHOLE BODY VIBRATION IN FORKLIFT DRIVERS.

Dear Sir/Madam

This letter serves to confirm that Portnet Management and the Labour of City Terminal and its employees are willing to co-operate in the above mentioned study being conducted at Portnet, Durban by Mr D.M. Joubert

We trust that our co-operation and assistance in the study will help to find solutions to this problem.

Yours faithfully

Signed

ARTHUR S. MZIMELA	**M.E. SIBISI**	**T.T. MBONA**	**H. JELE**
Senior Manager : Human Resources	**Representing DELATUSA**	**Representing SARHWU**	**Representing DELATUSA**

Signed

R.M. LUSHABA	**A. NAIDOO**	**C. ALLAN**
Representing SARHWU	**Risk Officer**	**Risk Manager**

APPENDIX D

APPENDIX D: English Questionnaire Instructions and Letter of Consent

QUESTIONNAIRE INSTRUCTIONS AND LETTER OF CONSENT

UNIVERSITY OF CAPE TOWN

Faculty of Medicine

Department of Community Health

Questionnaire on Lower Back Pain

Instructions.

A. Your answers to the questions in this questionnaire will be regarded as strictly confidential and will be used for research purposes only, to find solutions to the lower back problems experienced by forklift drivers. Please answer all questions as truthfully as possible.

B. Make sure you answer all the questions and do not miss any accidentally. If you do not understand a question, ask the supervisor for help.

C. Please read every question carefully before you answer it.

D. Answer all the questions by marking the correct space, only one answer per question is needed.

E. The questionnaire should only be answered by drivers of three(3) ton, four and a half (4.5) and five (5) ton forklifts.

Consent For Participation

I acknowledge that I understand the contents of this form and freely consent to participation in the study. I am aware that I may withdraw my consent at any time without prejudice.

Signed:______________________ Date:____________
Respondent

Signed:______________________ Signed: ______________
Witness Researcher

APPENDIX E

APPENDIX E: Zulu Questionnaire Instructions and Letter of Consent

INQUBO YEMIBUZO KANYE NENCWADI YESIQINISEKO

INYUVESI YASE CAPE TOWN

UMKHAKHA WEZOBUDOKOTELA

UMKHAKHA WEZEMPILO YOMPHAKATHI

Imibuzo ngezinhlungu zeqolo

IMIGOMO:

1.1 Izimpendulo zakho kulemibuzo izoba imfihlo bese isetshenziswe ophenyweni lokuthola indlela/amasu ngezinkinga eziphathelene nezinhlungu zeqolo ezibhekene nabashayeli be forklift. Sicela uphendule lemibizo engenhla ngokwethembekile.

1.2 Qiniseka ukuthi zonke izimpendulo ziphendulekile. Uma ungaqondi umbuzo, cela usizo kokuphethe (Supervisor)

C. Fundisisa imibuzo kahle anduba uphendule.

D. Phendula imibuzo kokufaka uphawu lwesiphambano/umugqa onikwe zona. Ufane uku nikeza impendulo eyodwa.

E. Imibuzo ifanele ukuphendulwa abashayeli abashayela amatone awu 3 nawu namaforklift amatoni awu 4.5, 5.

ISIQINISEKO NGOKUTHATHA INGXENYE KULOLUHLELO:

Ngiyaqinisa ukuthi ngikuzwile okuqekethwe yilefomu mayelana nokuzibandakanya nokufaka isandla kuloluphenyo. Ngiyazi futhi ukuthi ngingayekela ukuzihlanganisa naloluphenyo ngaphandle kokuhlangabezana nenkinga.

IGAMA LOPHENDULAYO — *USUKU*

IGAMA LOFAKAZI
UPHENYO NGENHLUNGU ZEQOLO — *UMPHENYI(RESEARCHER)*

APPENDIX F

APPENDIX F: English Questionnaire

QUESTIONNAIRE ON LOWER BACK PAIN.

Mark correct answer with a cross or write the answer in the space provided.

1. Age:__________________years

2. Race: Black ☐ 1 White ☐ 2 Coloured ☐ 3 Indian ☐ 4

3. Total number of years driving forklifts:__________________years

4. Number of years driving forklifts for Portnet:__________________years

5. What was your occupation before becoming a driver:________________________

6. Type of forklift driven the most: Old type ☐ 1 New Type ☐ 2 Other:_________ 3

7. Average number of hours driving per day:______________________ hours

8. Average number of hours worked per day:______________________ hours

9. Normal Work area: Point ☐ 1 Maydon wharf ☐ 2 Combi terminal ☐ 3

10. Do you regularly have pain or stiffness in the back? Yes ☐ 1 No ☐ 2

11. If yes, in what year did the back pain start?_____________________

12. If yes, where in the back do you have pain or stiffness? Shoulder area ☐ 1
    Middle back ☐ 2
    Lower back ☐ 3

13. Do you have back pain today? Yes ☐ 1 No ☐ 2

14. Did you have back pain in the last 12 months? Yes ☐ 1 No ☐ 2

15. Do you regularly get back pain during or shortly after driving a forklift? Yes ☐ 1 No ☐ 2

16. How long does the pain in your back usually last?

Several hours ☐ 1 Several days ☐ 2 Several weeks ☐ 3

Several months ☐ 4 Always present ☐ 5

17. Have you been on sick leave due to back pain in the last 12 months? Yes ☐ 1 No ☐ 2

18. If yes, for how many days?______________________days.

19. Have you ever been treated for back pain? Yes ☐1 No ☐2

20. If yes, by whom? Doctor ☐1 Traditional Healer ☐2 Other______________3

21. Do you take any medication to relieve back pain? Yes ☐1 No ☐2

22. If yes, where do you get it from? Doctor ☐1 Pharmacist/Chemist ☐2

Traditional Healer ☐3 Other ___________4

23. Have you ever had a back operation? Yes ☐1 No ☐2

24. How often during the day do you take a break from driving and walk around?

every hour ☐1 every two (2) hours ☐2 every four (4) hours ☐3

every six (6) hours ☐4 only at tea and lunch break ☐5

25. Do you play sport or do any other physical exercise? Yes ☐1 No ☐2

26. If so, how many hours per week?______________________hours.

27. What sport do you do? Squash ☐1 Soccer ☐2 Rugby ☐3

Weight training ☐4 Aerobics ☐5 Hockey ☐6 None ☐ Other: ______

28. Do you regularly do any of the following activities? Gardening ☐ Dancing ☐

Watch Television ☐ yes=1 no = 2

29. When you are driving a forklift do you do any of the following to prevent or reduce back pain?

Use a Cushion for back support ☐1 Back/kidney belt belt ☐2

Drive slower ☐3 Other(specify)________________4

None ☐5

30. If yes, how often do you do this, or use this? All the time ☐ 1

Sometimes ☐ 2

Rarely ☐ 3

31. If yes, has it helped to reduce the level of back pain? Yes ☐ 1 No ☐ 2

32. Do you always adjust the seat of the forklift before you use it? Yes ☐ 1 No ☐ 2

33. Do you know how to adjust the seat? Yes ☐ 1 No ☐ 2

34. How fast in your opinion do you drive your forklift ?

Slow ☐ 1 Average ☐ 2 Fast ☐ 3 Very fast ☐ 4

35. Please indicate on the line below the number between 0 and 100 that best describes the pain in your back when it is at its worst. A zero (0) would mean "no pain at all" and a hundred (100) would mean "pain as bad as it could be". Please write only one number!

0.......................|.........................|......................|........................100
25 50 75

36. Please indicate on the line below the number between 0 and 100 that best describes the pain in your back when it is at its least. A zero (0) would mean " no pain at all" and a hundred (100) would mean " pain as bad as it could be". Please write only one number!

0.......................|.........................|......................|........................100
25 50 75

BACK/KIDNEY BELT QUESTIONNAIRE

1. Do you use the back/kidney belt you have been given by Portnet?

YES	☐ 1
NO	☐ 2
I WAS NEVER GIVEN ONE.	☐ 3

2. If yes, how often do you wear it?

ALL THE TIME	☐ 1
SOMETIMES/OCCASIONALLY	☐ 2
RARELY/VERY SELDOM	☐ 3

3. In your opinion has the back/kidney belt reduced your back pain?

YES ☐ 1 NO ☐ 2

4. Mark the statements you AGREE or DO NOT AGREE with below:

	AGREE	DO NOT AGREE
4.1 The belts are too hot and uncomfortable	☐ 1	☐ 2
4.2 The belts are too much trouble to wear	☐ 1	☐ 2
4.3 The belt is comfortable	☐ 1	☐ 2
4.4 I do not wear it as it is lost/stolen	☐ 1	☐ 2
4.5 The belt fits me well	☐ 1	☐ 2
4.6 I do not use it as it is broken	☐ 1	☐ 2
4.7 I think the seat of the forklift needs to be changed	☐ 1	☐ 2
4.8 I do not know how to wear the belt I have been given	☐ 1	☐ 2
4.9 The belt has made my back muscles stronger	☐ 1	☐ 2
4.10 I would rather use some thing else to prevent my back pain	☐ 1	☐ 2
4.11 The back belt weakens my back muscles	☐ 1	☐ 2
4.12 The belt makes the back pain worse	☐ 1	☐ 2

APPENDIX G

APPENDIX G: Zulu Questionnaire

Ketha impendulo efanele ngoku beka isiphambano (x) esikhaleni osinikeziwe ngenzansi.

1. Iminyaka: ______________________

2. Uhlanga: Mnyama ☐ 1 Mhlophe ☐ 2 Ndiya ☐ 3 Coloured ☐ 4

3. Inani leminyaka ushayela iforklift: ______________________.

4. Iminyaka ushayela iforklift kaPortnet: ______________________.

5. Phambilini wawusebenza luphi uhlobo lomsebenzi anduba ube nguMshayeli: ______________________.

6. Shono uhlobo lwe-forklift olusebenzisayo: Endala ☐ 1 Olusha ☐ 2
olunye uhlobo: ______________.

7. Isingathekiso samahora owathathayo ngosuku ushayela iforklift: ______________

8. Isingathekiso samahora owasebenzayo ngosuku: ______________.

9. Indawo osebenzela kuyona: Point ☐ 1 Maydonwharf ☐ 2 Combi Terminal ☐ 3

10. Uyaye ubenazo izinhlungu zokuqina kweqolo njalo na? Yebo ☐ 1 Qha ☐ 2

11. Uma impendulo kungu Yebo, lezinhlungu zaqala ngawuphi unyaka? ______________

12. Lezinhlungu zindawanaphi neqolo, mhlwumbe Emahlombe ☐ 1
Phakathi neqolo ☐ 2
Ngezansi kweqolo ☐ 3

13. Unayo yini ihlungu yeqolo namuhla na? Yebo ☐ 1 Qha ☐ 2

14. Ukewanenhlungu ezinyangeni ezingu12 ezedlule na? Yebo ☐ 1 Qha ☐ 2

15. Uye ubenazo njalo lezinhlungu zeqolo noma zibakhona emveni kokushayela na?
Yebo ☐ 1 Qha ☐ 2

16. Zithatha isikhathi esingakanani lezinhlungu zeqolo.

Isikhashana ☐ 1 Izinsuku ezimbalwa ☐ 2 Amaviki ☐ 3 Izinyanga ☐ 4

Ngasosonke isikhathi ☐ 5

17. Uke wathatha ikhefu(livu) ngenxa yeqolo ezinyangeni ezingu12 ezedlue?

Yebo ☐ 1 Qha ☐ 2

18. Uma impendulo kunguYebo, zingaki izinsuku owazihlalayo ____________________

19. Uke watholoa ukwelashwa ngenxa yezinhlungu zeqolo? Yebo ☐ 1 Qha ☐ 2

20. Uma uthi Yebo, yimuphi udokotela owakulaphayo kulaba abalandelayo:

Wamathambo ☐ 1 Inyanga yesiZulu ☐ 2 Abanye: ________________

21. Ikhona imithi oyithathayo ukuphelisa lezizihlungu na? Yebo ☐ 1 Qha ☐ 2

22. Uma uthi Yebo, uyithola kuphi imithi? Dokotela ☐ 1 Ikhemisi ☐ 2

Inyanga yesiZulu ☐ 3 kwabanye: ________________ 4

23. Uke waba nalo uqhaqho loqolo na? Yebo ☐ 1 Qha ☐ 2

24. Kangaki osukwini uthatha ikhefu emveni kokushayela

njalo ngehora ☐ 1 njalo emahoreni awu2 ☐ 2

njalo emahoreni awu4 ☐ 3 njalo emahoreni awu 6 ☐ 4 ngesikhathi setiye ☐ 5

25. Uye udlale eminyeyemidlalo yokujuquzisa igazi (exercise)? Yebo ☐ 1 Qha ☐ 2

26. Uma kunjalo, amohora mangaki evikini owathathayo? ________________________

27. Iluphi uhlobo lomdlalo owudlalayo kulena Squash ☐ 1 Soccer ☐ 2 Rugby ☐ 3

Izinsimbi ☐ 4 Aerobics ☐ 5 Hockey ☐ 6

Okunye ________ 7 Lutho ☐ 8

28. Uhlale uyenza njalo yini lohlobo lomsembenzi? Ingadi ☐ Dansa ☐ Buka iTV ☐

Yes=1 No=2

29. Umangabe ushayela iforklift, uyaye ukwenze okungehla ukuze unciphise izinhlungu?

sebenzisa umqamelo ukusekela iqolo ☐ 1 Sebenzisa ibhande loqolo/lezinso ☐ 2

shayela kancane ☐ 3 Osebenzisi lutho ☐ 4 Okunye ___________.5

30. Uma uvuma, uyisebenzise kangaki lendlela? Njalo ☐ 1

Kancane ☐ 2

Kwenye inkathi ☐ 3

31. Kuyasiza yini ukusebenzisa lohlelo lokunciphisa izinhlungu? Yebo ☐ 1 Qha ☐ 2

32. Uyakwazi yini ukulingisa(adjust) ibhande lesihlalo seforklift? Yebo ☐ 1 Qha ☐ 2

33. Uye ulungise (adjust) ibhande lesihlalo anduba uyashayele ? Yebo ☐ 1 Qha ☐ 2

34. Singakanani isivinini ngokombono wakho oshayela ngaso iforklift ?

Ncane ☐ 1 Lingene ☐ 2 Phakathi ☐ 3 Khulu ☐ 4

35. Sicela ubonise ngezansi kulomugqa inani ongachaza ngalo inhlungu ehamba ngalo nanoma libuhlungu ngokweqile. U 0(zero) usho ukungabikho kwenhlungu bese u100 usho ukweqa kwenhlungu. Sicela ubhale inombolo kuphela

0.......................|.........................|.......................|.........................100
25 50 75

36. Bonisa emgqeni ongenzansi inombolo ephakathi kuka 0 no 100 echaza ubuhlungu oye ubuzwe. Bhala kuphela inombolo eyodwa.

0.......................|.........................|.......................|.........................100
25 50 75

Comments____

IMIBIZO NGEBANDE LEQOLO KANYE NEZINSO

1. Uyalisebenzisa yini ibhande olinikezwe nguPortnet ekuvikeleni inhlungu yeqolo noma izinso?

   YEBO ☐ 1

   QHA ☐ 2

   ANGIZANGE NGILINIKWE. ☐ 3

2. Uma impendulo ingu yebo, uyaye ulisebenzise kangakanani?

   NSUKU ZONKE ☐ 1

   NGAMANYE AMALANGA ☐ 2

   KUYAQABUKELA ☐ 3

3. Ngokombono wakho ibhande leqolo noma izinso liyazehlisa yini izinhlungu?

   YEBO ☐ 1 QHA ☐ 2

4. Bonisa ukuthi uyavumelana noma uyakuphikisa okushiwo emigqeni engenzansi

		VUMA	NOMA PHIKISA
4.1	Amabhande aqinile kanti awaphathani kahle	☐ 1	☐ 2
4.2	Amabhande anikezana inkinga uma uwafakile	☐ 1	☐ 2
4.3	Ibhande aliphathani kahle	☐ 1	☐ 2
4.4	Angilifaki ibhange ngoba liyalahleka noma lintshontshwe	☐ 1	☐ 2
4.5	Ibhande lingilingana kahle	☐ 1	☐ 2
4.6	Angilisebenzi ibhande ngoba lidabukile/hlephukile	☐ 1	☐ 2
4.7	Ngicaba ukuthi isihlalo seforklift sidinga ukushintshwa	☐ 1	☐ 2
4.8	Angiqodi kahle ukuthi lifakwa kanjani ibhandeengilinikeziwe.	☐ 1	☐ 2
4.9	Ibhande lenza imisipha yeqolo iphile kangcono	☐ 1	☐ 2
4.10	Ngicamela ukusebenzisa okunye ekuvimbeni izinhlungu zeqolo	☐ 1	☐ 2
4.11	Ibhande leqolo lenza buthakakatha imisipha yeqolo	☐ 1	☐ 2
4.12	Ibhande lenza izinhlungu zedlulele	☐ 1	☐ 2

APPENDIX H

APPENDIX H: I.S.O Guideline Document ISO-2631/1 (1997) Mechanical Vibration and Shock -Evaluation of Human Exposure to Whole-Body Vibration.

1.0 Introduction

This document addresses methods for the measurement of periodic, random, and transient whole-body vibration. It indicates the principal factors that combine to determine the degree to which a vibration exposure will be acceptable. The frequency ranges considered are and 0.1 to 0.5 for motion sickness and 0.5 to 80 Hz for health, comfort and perception. The document is applicable to motions transmitted to the human body as a whole through the supporting surfaces: the feet of a standing person, the buttocks, the back and feet of a seated person or the supporting area of a recumbent person.

2.0 Standards Of Measurement And Analysis Of Whole-body Vibration Exposures.

Whole-Body Vibration for seated operators is usually measured in three orthogonal directions (see figure below) such that the x-axis is in the direction of travel and the y-axis is transverse to it. The z-axis is in the vertical direction passing from the seat to the head of the operator (for seated persons) or from the feet to the head of the operator (for standing persons). Measurements in the x-axis on the backrest are encouraged by ISO 2631 (1997) for seated persons. However, considering the shortage of evidence showing the effect of this motion on health, it is not included in the assessment of the vibration severity given in ISO 2631 (1997).

3.0 Measurement Techniques And Equipment.

The severity of occupational whole-body vibration exposure is measured using sophisticated, yet easy to operate vibration analysis equipment.

Several issues must be taken into consideration in order to get meaningful and accurate results (Thalheimer 1996). These include the calibration of the measurement system, the capabilities of the transducer and whole measurement system to properly measure the dynamic levels and frequency ranges associated with the measurements, the transducer/accelerometer attachment or mounting techniques, the proper configuration of the measurement system to yield vibration metrics of interest, and the recording of the vibration data and results for further processing and analysis.

The most common system uses a vibration transducer to transform the mechanical motion into an electrical signal, an amplifier to enlarge the signal, an analyser to measure the vibration in specific frequency ranges, and a measuring device calibrated in vibrational amplitude units.

3.1 Transducers/Accelerometers

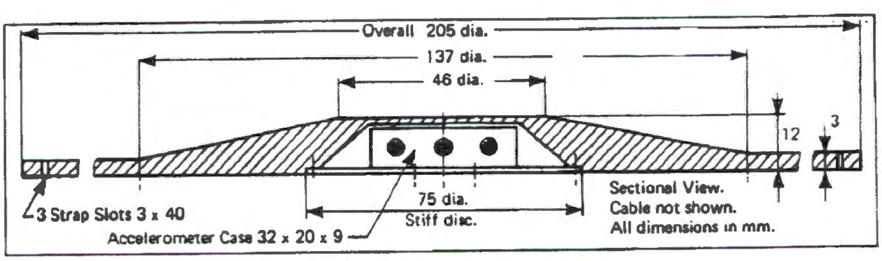
The measurement of vibration requires making contact with the vibrating surface in question, usually the seat surface on which the driver sits. In the past, vibration transduction was accomplished through the use of strain gauges to measure a surfaces movement. More recently piezo-electric transducers known as accelerometers have been favoured. These are typically a sealed device within which a small piece of piezo-electric material between the accelerometers base (or housing) and a small attached moving mass. As the mass accelerates (moves) due to the vibrating surface, the piezo crystal is stressed and produces an electronic signal or voltage on their surfaces due to the mechanical strain on the asymmetric crystals proportional to the acceleration of the surface, the output voltage is thus proportional to the acceleration and thus to the vibrational signal. The strain is in the form of vibrational inertia from a moving mass atop the discs. The upper limit of the accelerometer's useful frequency range is determined by the resonant frequency of the mass and the stiffness of the whole accelerometer system. The lower limit of the frequency range varies with the cable length and the properties of the connected amplifiers. The accelerometer's sensitivity and the magnitude of the voltage developed across the output terminals depends on the properties of the materials used in the piezoelectric discs and the weight of the mass. The mechanical size of the accelerometer, therefore, determines the sensitivity of the system; the smaller the accelerometer, the lower the sensitivity. In contrast, a decrease in size results in an increase in frequency of the accelerometer's resonance and, thus, a wider useful range. Other factors to consider in the selection of a suitable accelerometer include the transverse sensitivity (which is the sensitivity to accelerations in a plane perpendicular to the plane of the discs) and the environmental conditions during the accelerometer's operation (primarily temperature, humidity, and varying ambient pressure).

Often, two types of sensitivities are stated by the manufacturer: voltage sensitivity and charge sensitivity. Voltage sensitivity is important when the accelerometer is used in conjunction with voltage measuring electronics. Charge sensitivity, an indication of the charge accumulated on the discs for a given acceleration, is important when the accelerometer is used with charge-measuring electronics.

Since the acceleration, velocity, and displacement for non-random vibration are all interrelated by differential operations, all of the variables can be measured with an accelerometer.

The size and sensitivity of an accelerometer are essential attributes to consider when selecting an appropriate transducer for a given measurement. Sensitivity indicates the amount of signal a transducer will generate given some normalised amount of vibration. In general the larger the size of the accelerometer the greater its sensitivity. For whole-body vibration measurements a medium sized accelerometer should be selected specifically designed for low frequency application of less than 1 Hz.

Figure 1 Shows a cross sectional view of a whole-body vibration seat transducer or accelerometer.



Whole-Body Seat Transducer sectional view

Source: Bruel & Kjaer (1985).

3.2 Pre-amplifiers

The pre-amplifier is introduced in the measurement circuit for two reasons: 1) To amplify the weak output signal from the accelerometer; and 2) to transform the high output impedance of the accelerometer to a lower, acceptable value. It is possible to design the pre-amplifier in either of two ways: one in which the pre-amplifier output voltage is directly related to the input voltage (a voltage amplifier); and one in which the output voltage is proportional to the input charge (a charge amplifier).

The major difference between the two types of amplifiers is in their performance characteristics. When a voltage amplifier is used, the overall system is very sensitive to changes in the cable length between the accelerometer and the pre-amplifier, whereas changes in cable length produce negligible effects on a charge amplifier. The input resistance of a voltage amplifier will also affect the low-frequency response of a system.

3.3 Accelerometer Mounting Techniques

Thalheimer (1996) points out that the method with which the accelerometer is attached to the vibrating surface can play a significant role in the resulting capabilities of the sensor to transduce vibration.

Several mounting techniques are available, and in general the more stiff the mounting technique the better the surface vibration will couple and transfer to the accelerometer. Mounting could be carried out using adhesives, magnetic mounts, bees wax and direct placement on the vibrating surface. For whole-body vibration a dedicated tri-axial accelerometer housed in a rubber disc shaped pad is preferred in accordance with the ISO-2631(1997) requirements, which states that measurements on the supporting seat surface should be made beneath the ischial tuberosities. The pad was taped in place on the seat surface, and allowed test subjects ie: drivers, to sit on the accelerometer while still performing the driving task. According to ISO-2631(1997), vibration which is transmitted to the body from a non-rigid material, such as a seat cushion, should be measured with the transducer interposed between the person and the principal contact areas of the surface. In this manner vibration is transduced at the point in which it enters the drivers body in three mutual orthogonal directions.

3.4 Vibration Calibrators

To ensure that measurement instrumentation is properly configured and connected for measurement, a calibration source is essential. A vibration calibrator produces a known vibration level at a known frequency, which can be used to generate a known response from a vibration measurement system or by using electrical charges to identify any charge drop through the system. In South Africa the requirements for laboratory certification and competence are laid down in a South African Bureau of Standards Code of Practice S.A.B.S 0259:1990, which is equivalent to the I.S.O/I.E.C. guide 25:1990, and looks at the general requirements for competence of calibration and testing laboratories.

Any calibration system used must be certified to higher level of calibration standard, this is achieved in South Africa by sending monitoring and sampling equipment annually to an approved laboratory that can conduct primary calibration of the equipment under controlled laboratory conditions. This included all equipment used from the oscilloscope to the accelerometers. This ensures the user that the equipment they are relying upon to give an accurate vibration source level has been calibrated to a higher accuracy reference level under standard controlled laboratory conditions.

3.5 Data Capture

The raw vibration data electronic signal can then be passed through a series of charge amplifiers and sent via a telemetry system and aerial for real time capture on a nearby personal computer. This is then subjected to frequency analysis at a later stage.

3.6 Frequency Analysis.

The frequency of vibration is very important when consideration of effects and exposure limits is taken, and for this reason analysis of the frequency has to be carried out on the raw vibration data. The frequency analyser determines the distribution of acceleration in different frequency bands. The frequency weighting networks mimics the human sensitivity to vibration of different frequencies. The use of weighting networks gives a single number as a measure of vibration exposure and is expressed as the frequency-weighted vibration exposure in metres per second squared (m/s^2), units of acceleration. Measurement devices are able to filter selected frequency ranges (or bandwidths) for measurement. By doing this type of filtering at many different frequencies the vibrations spectral composition can be determined.

4.0 Evaluation of Vibration Exposure Characteristics

ISO 2631 (1997), Part 1 defines and provides frequency filters for four principal effects of vibration, i.e.:

-degraded health
-impaired activities such as hand control and vision
-impaired comfort
-motion sickness

Different frequency weighting's are required for different axis of vibration and for the different effects of vibration on the body.

Various methods and criteria are used to evaluate the different characteristics and components of vibration exposure, these criteria as used for the hazard evaluation are discussed below:

Weighted acceleration levels in metres per second squared (m/s^2) are usually expressed as Weighted Root-Mean Squared (RMS_W) values. This provides for a number presenting an average acceleration integrated over a certain time period.
Weighted Maximum Peak Acceleration levels provide information on shock loads which would otherwise be lost in the RMS acceleration levels. This particularly significant with equipment which often encounter obstacles in their pathways, have inadequate suspensions or poor seating.

Crest Factor (CF) helps to define the roughness of a particular ride. They are the ratio of the weighted peak acceleration level to its corresponding weighted RMS value.

Vibration Dose Value (VDV) in $m/s^{1.75}$ is defined as the relation between vibration magnitude and duration. It has the advantages that it is not limited to low crest factor motions and it may be applied to intermittent vibration exposures, to repeated shocks and also to those exposures consisting of periods of vibration at different magnitudes.

Multi-axis RMS vibration levels are determined from the square root of the RMS vibration in the orthogonal co-ordinates.

$$RMS_{multi\text{-}axis}=\sqrt{k_x^2 RMS^2_{xw}+k_y^2 RMS^2_{yw}+k_z^2 RMS^2_{zw}}$$

Multi-axis VDV in m/s1.75 is determined from the fourth root of the Vibration Dose Values (VDV) in the orthogonal co-ordinates.

$$VDV_{multi\text{-}axis}=\sqrt[4]{k_x^4 VDV^4_{xw}+k_y^4 VDV^4_{yw}+k_z^4 VDV^4_{zw}}$$

The total vibration dose value for a longer period of time is given by the fourth root of the fourth power of the vibration dose value, VDV, (for period t_1) after multiplication by t_0/t_1 (where t_0 is the longer period of vibration exposure).

The calculation of exposure limit, FDPB (Fatigue-decreased proficiency boundary) and reduced comfort boundary when analysing whole-body vibration have been made obsolete with the replacement of ISO-2631 (1985) with ISO-2631 (1997). These parameters were not calculated in the Portnet study.

To determine the effectiveness of the seats in attenuating vertical vibration (z-axis), S.E.A.T. (Seat Effective Amplitude Transmissibility) values were calculated using the formula:

$$S.E.A.T.\ (\%) = \left[\frac{\int G_s(f) \cdot W_i^2(f)\, df}{\int G_f(f) \cdot W_i^2(f)\, df} \right]^{1/2} X\ 100$$

Where $G_s(f)$ and $G_f(f)$ are seat and floor acceleration power spectra and $w_i(f)$ is the frequency weighting for the human response to vibration, which in this case was the W_k weighting (ISO 2631).. The degree to which the S.E.A.T. is less than 100% indicates the amount of attenuation provided by the seat over the frequency range 0.1 Hz to 80 Hz and is weighted for the response of the human body.

The degree to which the S.E.A.T. is more than 100% indicates the amount of amplification of the vibration by the seat over the ranges above. A completely rigid seat will have a transmissibility coefficient of 100%.

APPENDIX I

APPENDIX I: Measurement Equipment List and Calibration Dates

EQUIPMENT	SERIAL NUMBER	CALIBRATION DATE
SYSTEM SETUP		
B&K TYPE 4371 ACCELEROMETER	1341042	JAN '98
B&K TYPE 4294 CALIBRATION	1332039	JAN '98
B&K TYPE 2813 EXCITER LINE DRIVE SUPPLY	1357067	JAN '98
B&K TYPE 2644 LINE DRIVE	1337843	JAN '98
CALIBRATION CAPACITOR	VGAP	JAN '98
GOULD OSCILLOSCOPE	58664017	JAN '98
WAVETEK M19 FUNCTION GENERATOR	25060	JAN '99
PCB MODEL 424A CHARGE	328	NOT REQUIRED
AMPLIFIERS 424A CHARGE	332	NOT REQUIRED
AMPLIFIERS 424A CHARGE	329	NOT REQUIRED
AMPLIFIERS 424A CHARGE	342	NOT REQUIRED
AMPLIFIERS 424A CHARGE	335	NOT REQUIRED
AMPLIFIERS 424A CHARGE	338	NOT REQUIRED
AMPLIFIERS 424A CHARGE	330	NOT REQUIRED
AMPLIFIERS 424A CHARGE	339	NOT REQUIRED
MEASUREMENT		
B&K TYPE 4322 TRI-AXIAL ACCELEROMETER	1354172	JAN '98
B&K TYPE 4322 TRI-AXIAL ACCELEROMETER	1306255	JAN '98
B&K TYPE 4371 ACCELEROMETER	1341039	JAN '98
B&K TYPE 4371 ACCELEROMETER	1341042	JAN '98
PCB MODEL 424A CHARGE AMPLIFIES	328	NOT REQUIRED
PCB MODEL 424A CHARGE AMPLIFIES	332	NOT REQUIRED
PCB MODEL 424A CHARGE AMPLIFIES	329	NOT REQUIRED
PCB MODEL 424A CHARGE AMPLIFIES	342	NOT REQUIRED
PCB MODEL 424A CHARGE AMPLIFIES	335	NOT REQUIRED
PCB MODEL 424A CHARGE AMPLIFIES	338	NOT REQUIRED
PCB MODEL 424A CHARGE AMPLIFIES	330	NOT REQUIRED
PCB MODEL 424A CHARGE AMPLIFIES	339	NOT REQUIRED

APPENDIX J

APPENDIX J: Summary of Whole-Body Vibration Results

Fork-lift	Condition	Multi-axis RMS	Seat (%)
Point Terminal			
A	Rough Unadjusted	3.05	106.83
	Smooth Unadjusted	2.04	104.84
B	Rough Adjusted	1.91	149.60
	Rough Unadjusted	2.88	160.36
	Smooth Adjusted	1.45	151.62
	Smooth Unadjusted	1.58	133.21
C	Rough Adjusted	1.18	84.05
	Rough Unadjusted	1.19	75.64
	Smooth Adjusted	0.82	92.05
	Smooth Unadjusted	0.82	75.67
D	Rough Adjusted	1.31	97.05
	Rough Unadjusted	1.17	81.46
	Smooth Adjusted	1.07	108.57
	Smooth Unadjusted	0.83	76.33
Maydon Wharf			
E	Rough Adjusted	1.33	102.41
	Rough Unadjusted	1.54	120.74
	Smooth Adjusted	0.48	138.41
	Smooth Unadjusted	0.47	151.42
F	Rough Adjusted	1.51	168.31
	Rough Unadjusted	1.36	56.95
	Smooth Adjusted	0.75	173.92
	Smooth Unadjusted	0.97	222.56
Combi Terminal			
G	Rough Adjusted	0.82	38.28
	Rough Unadjusted	1.36	56.95
	Smooth Adjusted	0.64	48.20
	Smooth Unadjusted	0.84	54.08
H	Rough Unadjusted	1.06	131.86
	Smooth Unadjusted	0.74	118.39
J	Rough Adjusted	0.78	133.15
	Rough Unadjusted	0.74	129.59
	Smooth Adjusted	0.58	138.52
	Smooth Unadjusted	0.57	129.13
Loaded	Rough Adjusted	0.54	134.73

APPENDIX K

APPENDIX K: Recommended Seating Design Guidelines.

1. Introduction

The following sections expand on the principles of seating design for mobile underground mining machinery as recommended by the Pittsburgh Research Laboratory, (Pittsburg Research Laboratory 1997. Available on-line from URL:http://www.cdc.gov/niosh/pit/hfg_seat1.html.), but could be adapted for other industrial applications such as a forklift seat which also needs to be employed in an area with space limitations and often harsh conditions, both environmental and operational.

1.2. Seat Dimensions

A good fitting seat depends on many anthropometric and biomechanical factors, which highlights the need for extensive data collection in these areas, so that better seats can be designed to suit the drivers that will be using them. Different shapes and sizes of workers suggest that a seat be adjustable by moving it in the up-down and in the fore-aft directions to ensure adequate reach of controls, and proper body support and comfort.

1.3. Seat Height

As the height of the seat increases beyond the popliteal height of the user, pressure will be felt on the underside of the thighs. The resulting reduction of circulation to the lower extremities may lead to a "pins and needles" feeling, swollen feet, and considerable discomfort. As the height decreases, the user will flex the spine more (due to the need to achieve an acute angle between the thigh and trunk), experience greater problems in standing up and sitting down, due to the distance through which his centre of gravity must move, and require greater leg room. Usually, the optimal seat height for many purposes is close to the popliteal height. If this is not possible, a seat that is too low is preferable to one that is too high. For many purposes, the 5th-percentile female popliteal height represents the best compromise. If making a seat higher than this is necessary (e.g., to increase the eye height for better visibility), which is very applicable to forklift operations, as often tall loads are carried which does not allow clear forward visibility and therefore forces the driver to reverse and twist his body, the ill effects may be mitigated by shortening the seat and rounding off its front edge to reduce the under-thigh pressure.

1.4. Seat Pan Depth

If the design increases the seat pan depth beyond the buttock-popliteal length, the user cannot engage the backrest effectively without putting pressure on the backs of the knees.

This is already a problem in some drivers, where the seat pan depth may be satisfactory, but because they do not move the seat forward they are forced to lean forward to grasp the steering wheel and this causes the back to lose contact with the back rest and any lumbar support provided. Furthermore, the deeper the seat pan, the greater the problems of standing up and sitting down which can lead to back strain or injury when exiting the vehicle.

1.5. Backrest

The higher the backrest, the more effective it will be in supporting the weight of the trunk. This is always desirable, but in some circumstances other requirements, such as the mobility of the shoulders needed to look to the rear, may be more important. This is especially important in forklifts when reverse driving with tall loads is carried out, as a high backrest would restrict the movement of the driver and his rear vision. However if twisting and turning of the torso could be avoided altogether this would reduce the risk of back injuries from these awkward postures.

1.6. Seat Width

Most people require a width between 45.7 cm and 50.8 cm for support. This distance should provide adequate clearance between the armrests for the largest user. Many older drivers are overweight with large paunches due to the slackening of the abdominal muscles and perhaps linked to the sedentary nature of their job, as well as the fact that most of them do not do other physical exercise like sports. This causes a problem in two ways, firstly it causes them to assume awkward postures to "fit" into the small space provided by the seating area, and secondly they often break the seat cushions and spring system with their weight, thereby making the seat less effective in offering protection.

1.7. Seat Pan to Seat Back Angle

This angle should be between 100 and 165 degrees as the seat back approaches the vertical position and be adjustable to ensure adequate support for each driver. As the backrest angle increases, a person supports more of the weight of the trunk; therefore, they diminish the compressive force between the trunk and pelvis. However, the horizontal component of the compressive force increases. This will drive the buttocks forward out of the seat unless counteracted by an adequate seat tilt, high-friction upholstery, or muscular effort from the subject. An increased seat back angle also leads to increased difficulty in getting into and out of the seat which increases the risk of injury.

1.8. Seat Pan Angle

The angle of the seat pan relative to the cab floor is important for comfort and body support during rapid decelerations or collisions. However excessive tilt reduces the hip-trunk angle and makes getting in to and out of the seat more difficult.

1.9. Armrests

Armrests may give additional postural support and be an aid to standing up and sitting down. Armrests should support the fleshly part of the forearm, but unless very well padded they should not engage the bony parts of the elbow where the highly sensitive ulnar nerve is near the surface. Arm rests should tilt up and out of the way when not in use and be adjustable in both height and angle. Some forklifts of the older type and models do not have any armrest support and this also leads to driver fatigue as the arms must always be physically supported throughout the work shift.

1.10. Seat Surface and Coverings

The seat surface should be mostly flat rather than shaped, although a rounded front edge is desirable to reduce under-thigh pressure. The sides of the seat pan can be raised slightly to aid in postural stability during lateral accelerations. The covering materials should be waterproof and rough to aid stability. Many forklifts have torn seat coverings due to the operating conditions and long hours drivers spend in the seat, and this expose the cushioning material to the elements and cause its rapid deterioration, as well as allowing water to soak in and causing an uncomfortable ride for the unfortunate driver. The seat stitching is usually the weak point on the cover, as most deterioration has been as a result of the stitching coming loose, rather than tears in the material.

1.11. Vibration Isolation

Vibration isolation is a very important component that should be designed into the seat-workstation installation to reduce operator exposure to bumps, jolts, and other mechanical shocks with all the associated adverse health effects as discussed earlier.

This isolation is generally achieved by a spring and shock absorber or damper system, although cushions are used primarily for static comfort, they are also effective in decreasing the transmission of vibration above the resonance range of the human body. They are ineffective in the resonance range and may even amplify the vibration in the sub-resonance range.

This is often the only damping protection offered by the older seats that are basically a cushion built on to a wooden frame or chassis. The seat should also offer lateral support (as in a concave seat back) against jerks, heavy swaying, or shocks while driving. The shock-absorbing qualities of the seat should be suitable for fitting operators ranging in weight from the 5th-percentile female to the 95th-percentile male.

A passive (moulded seat pan) or active (seat belt) occupant restraint system should also be incorporated into the seat-workstation to prevent the operator from being thrown out of the seat during a turn, hard bump, or collision.

Roof Height	Pan Angle from Floor.	Back to Pan Angle.	Head Rest to Back Angle.
91.4 cm or more.	15 -30 Degrees.	100 - 165 Degrees.	130 -170 Degrees.

Head Rest Travel Along Back.	Seat and Head Rest Width.	Pan Length.	Height of Back.
17.8 cm.	45.7 - 50.8 cm.	30.5 - 61.0 cm.	40.6 - 61.0 cm Adjustable.

Table 1.1: Shows Seating Specifications (From Pittsburgh Research Laboratory, Mining Health. and Safety Research Available on-line at URL:http://www.cdc.gov/niosh/pit/hfg_seat1.html).

1.12. Workstation Integration

All seat adjustment levers, knobs, or buttons should be within hand's reach by the 5th-percentile female and 95th-percentile male operators. They should not block ingress or egress, and should not pose impact hazards in the event that unexpected machine motions throw the operator from the seat.

All adjustment operations should be quick and should not require great force or the use of tools. The seat adjustment controls and moving parts should be able to be operated without risk of trapping fingers and should be designed so that they cannot be inadvertently removed. The adjustments should lock in all positions and should be spring loaded, where necessary, to help the operator in moving forward to a more upright position. All operating instructions should be clear and permanently displayed near the seat. Any seat maintenance programme should incorporate the maintenance of these adjusters. and full training in their use should be given as part of the forklift drivers training or licence application, and the inspection of these devices should be included in the pre-work inspection schedule carried out before each shift by the driver of a forklift. It must be borne in mind that any vibration control mechanism or procedure that relies on the driver, requires a degree of human motivation, co-operation, understanding and often behaviour modification, that needs a strong ongoing training and educational programme to ensure compliance and success.

Scales should be readily available to the drivers so they can weigh themselves and adjust the seat accordingly to ensure proper weight-damping seat settings.

The seat should not interfere with trunk, head, or limb movements needed to operate the machine. The seat should not restrict the operator's ability to see primary visual attention locations such as to the left and right, straight ahead and to the rear, and in any direction where visibility is needed for safe operation of the vehicle.

1.13. Seat Maintainability

The seat pan and backrest covers should be easily changed or repaired and should be washable so that they can be maintained in good condition. The edges of the seat assembly should be smoothed or rounded so as not to catch clothing or equipment.

The seat adjustment mechanisms should be self-cleaning and be able to withstand excessive water, dirt, and debris but must also be included in any maintenance or service programme. The seat assembly construction should be robust, and the seat should feel solid and safe to the user. The seat should be easily removed from the vehicle to effect repairs or to be replaced.

These considerations should be taken into account when new seats are designed, but also need consideration for retrofitting of older forklifts that have inadequate seating, and offer almost no protection to the driver. Systems and facilities for the retrofitting and upgrading of older forklifts are desperately needed in South Africa in order to improve the existing conditions until these forklifts reach the end of their operational life. This may be long past the manufacturers expectations, as the monetary exchange rates continue to weaken the rand which can then buy less, thus the older forklifts have to stay in service longer before upgrading and replacement. The design considerations mentioned can be used to evaluate the existing seats and identify non-compliant or inadequate seats. It is also important to inform any suppliers of new forklifts what the requirements are and insist they include proper ergonomic seat design in any desired specifications or requirements and any other factors already discussed that may effect the health and safety of the operator.