ABSTRACT

LONG DRIVING HOURS AND HEALTH OF TRUCK DRIVERS

by
Stephen J.Benstowe

In recent time, the health of truck drivers has become a concern for regulatory agencies and safety professionals all over the world. Fatal and non-fatal injury rates for truck drivers are among the highest of all occupations. Truck driving is an important and tedious job. Driving for long hours, drivers are confined to a small space, sit with static lower and upper extremities posture, mentally focus and absorb vibrations.

This thesis provides an in-depth review of the literature related to the problems of long distance truck drivers and commercial motor vehicle operators. The Literature suggests that continuous exposure of truck drivers to risk factors has led to such illnesses as musculoskeletal disorders, obesity, hypertension, cardiovascular disease, stroke, sleep disorders and psychological distress.

Prolonged sitting, whole-body vibration, physical and psychological fatigues were found to be the main risk factors that are related to the occupational health problems of truck drivers. These occupational risk factors were analyzed in detail to understand the physiological pathways that cause the risk factors to affect truck drivers' health. Based on these analyses, a set of suggestions on continuous improvement was made in areas of rest break, physical exercise, health monitoring, and psychological well being.

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by
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To my beloved parents Senibo Zachariah and Emily

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LIST OF SYMBOLS (or NOMENCLATURE, DEFINITIONS, etc.)

BLS	Bureau of Labor Statistics
FMCSA	Federal Motor Carrier Safety Administration
LBP	Low Back Pain
mm Hg	Millimeters of mercury
MSD	Musculoskeletal Disorder
ISO	International Standards Organization
N.J.S.A	New Jersey Statutes Annotated
NTSB	National Transportation Safety Board
NIOSH	National Institute of Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
TVD	Traumatic Vasospastic disease
U.S	United States
VWF	Vibration induced white finger
WF	White finger

CHAPTER 1

INTRODUCTION

In recent years, the health of truck drivers has become a concern both in the United States and abroad (Boyd, 2003; Hancock et al .2001). According to researchers and safety analysts, truck driving is ranked as one of the most dangerous occupations in the world (Boyd, 2003; Brown, 2002; Pegula, 2004). It is also the occupation ranked as having "the greatest number of injuries and illnesses" according to occupational health experts (Wiatrowski, 2005). The work of a truck driver involves a wide range of tasks associated with the control of a large and often heavily loaded vehicle, and it also exposes the driver to all the hazards of a heavy traffic environment.

Over the years there has been a deterioration in driving conditions, which is largely the result of traffic congestion, road and vehicle conditions, as well as the associated air and noise pollution. At the same time, there are ever-increasing pressures of adhering to a demanding schedule in circumstances that make the task of meeting deliveries almost impossible (Boyd, 2003). In all circumstances, the driver must absorb the failures of the transport system, which results in increased stress levels, conflict with customers, and the intensification of a wide range of work pressures in a hostile traffic environment. These circumstances impact the health of drivers in a way that is becoming unacceptable (Boyd, 2003; Wiatrowski, 2005).

Truck driving is a profession that is vital to the economy of every country, yet it is a career about which most people know very little. Larsen (2004) reported that surveys of the general public indicate that most people are ambivalent about truck driving and view it as a dead-end profession requiring little intelligence or skill. Nonetheless, people all over the world are dependent upon truck drivers one way or the other, and the work they perform. Manufactured goods from different parts of the world and within the country are moved to final destinations by long haul truckers.

A truck at some point and time transports nearly all goods consumed in the world. According to the American Transportation Research Institute (2004), the trucking industry hauled 68.9% of all freight transported in the United States in 2003, equaling 9.1 billion tons. The trucking industry was a $610 billion industry in the same year under review, representing 86.9% of the nation's freight bill. Trucks transport the "tangible" goods portion of the economy, which is nearly everything consumed by households and businesses. Trucking also plays a critical role in keeping costs down throughout the business community. Specifically, for businesses that produce high-value, low-weight goods, inventory-carrying costs can be considerable. Many of these producers now count on trucks to deliver products efficiently and in a timely manner so that inventory can be kept as low as possible and warehouse operating cost can be lowered.

In 2003, over 24 million trucks of all classes hauled over 9 billion tons of freight, and in the same year, all trucks used for business purposes logged a total of about 444 billion miles, which accounted for 15.6% of all motor vehicle miles and 37.6% of all truck miles (American Trucking Association, 2004). The trucking industry is a major employer in the U.S. Across all industries, almost 8.6 million people were employed in trucking-related jobs in 2003. Over 3 million of these people were truck drivers. Due to the importance of truck driving, regulatory agencies all over the world are very concerned about the hazards involved in the profession, both in terms of the direct threat these hazards present to drivers and the danger pose to the public (Wiatrowski, 2005).

Some of the occupational hazards impact a driver's health negatively. An extended driving period, increases the risk for fatigue and fatal inattentiveness, the time a driver spends on the road involves other risk factors as well. Prolonged sitting, which exposes the driver to vibrations, can have a negative impact on spinal and organ health (Makhsous, et al, 2005; Minter, 2003). Other physical hazards include exposure to emissions, chronic fatigue, and persistent sleep deprivation (Charlton et al. 2001).

It is widely recognized that long-haul trucking presents significant occupational hazards for drivers (Bureau of Labor Statistics, 2006). Although the Bureau of Labor Statistics (2006) acknowledges that "truck driving has become less physically demanding because trucks now have more comfortable seats, better ventilation, and improved ergonomically designed cabs, driving for many hours at a stretch, loading and unloading cargo, and making many deliveries can be tiring". .In fact, research substantiates that truck drivers are at increased risk for numerous preventable diseases, such as myocardial infarction, musculoskeletal disorders, hypertension, ulcers, and cancers of the lung, prostate, and bladder when compared to people in other professions (NIOSH, 2005, Bridger, 2003).

In addition to physical threats, long-haul truck driving is also taxing psychologically, which can exacerbate existing health problems. Long-haul truck drivers are more stressed when compared with other commercial drivers. All professional drivers are expected to perform what is called "threat-avoidant vigilant activity" (Belkic, 2000), requiring a high level of attention, the ability to process a large amount of information and stimuli from different sources, and the ability to react quickly in high-stakes situations. A momentary lapse in one's focus or a seemingly simple wrong decision can have serious, and even fatal, consequences. Belkic (2000) cites the medical literature, and claims that threat avoidant vigilant activity is highly stressful and often results in stress-induced medical problems, including heart attacks.

1.1 Study Objective

Considering the large numbers of people in the profession of truck driving, it is very important to research ways to prevent or reduce the risk of any adverse health conditions of truck drivers. Many factors may interact with each other. It may be possible, for instance, that stress level, age, and existing health conditions such as obesity interact with long hours and exposure to negative environmental conditions, thereby creating or increasing one's vulnerability to serious physical problems. The findings of this research can benefit not only the drivers themselves, but also their companies, all members of the supply chain, consumers, and the general public.

The objective of this study is to investigate occupational health effects on commercial truck drivers by conducting a comprehensive literature review on the impact of long driving hours and exposure to hazards on truck drivers. Based on the literature survey, a broad overview of various risk factors associated with truck driving and their health effects will be presented in the next chapter. The major risk factors namely, prolonged sitting, whole-body vibration, and fatigue appeared to be most critical and are of particular interest. An in depth study has been performed of these risk factors, which are described in the subsequent chapters. The author of the study will conclude with a set of evidence-based recommendations intended to result in improvements in the working environment of this group of professionals.

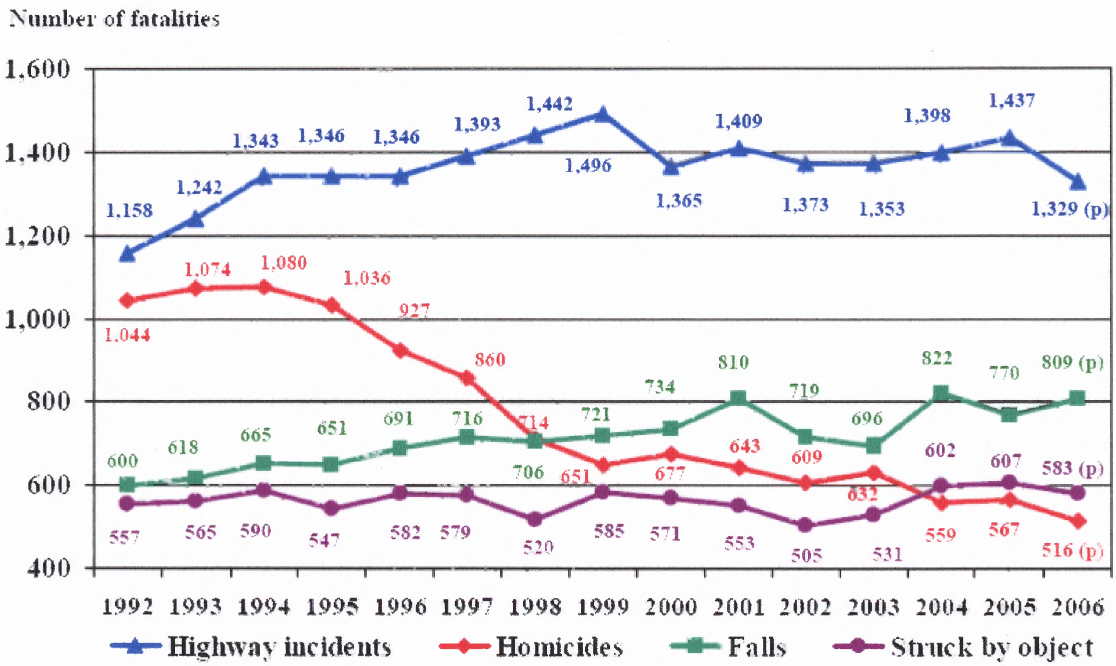
CHAPTER 2

OCCUPATIONAL HEALTH STATUS OF TRUCK DRIVERS

Literature searches were conducted using the following databases: NJIT Library, MEDLINE, PUB MED, SCOPUS, and BIOMED CENTRAL. The key words used were: "long working hours", "working time", "fatigue", "health", "safety", "low back pain", "whole-body vibration", and "truck drivers." To keep the review to a manageable size, it was decided to concentrate solely on studies relating to the problems of prolonged sitting, the health effects of whole-body vibration and fatigue. Articles from academic journals were retrieved. Additional information was retrieved from regulatory bodies, such as the Occupational Safety and Health Administration (OSHA), the National Institute of Occupational Safety and Health (NIOSH) and the Federal Motor Carrier Safety Administration (FMCSA), which have conducted extensive studies on the subject of truck driver's health and safety. Internet searches were also carried out, with relevant websites noted and several articles downloaded. Other articles were chosen from the reference lists contained in some of the more general review papers. The purpose of this chapter is to present a general overview of the health status of truck drivers.

2.1 Work Related Injuries in Transportation Industry in US

According to the Bureau of Labor Statistics (BLS), US Department of Labor (2007), highway incidents caused by far the highest number of fatal workplace incidents during the past 15 years (Figure 2.1) within the US private industry sector. The annual fatalities from highway incidents were consistently greater than the sum of three other leading causes, namely homicides, falls, and struck by objects. The latest data for 2006 on US workplace fatalities show that this trend remained unchanged. Fatalities due to highway incidents alone accounted for nearly one out of every four work injuries in 2006 (Figure 2.1). Fatalities in the transportation industry accounted for 44% of fatalities of all industries.



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NOTE: Data from 2001 exclude fatalities resulting from the September 11 terrorist attacks.
SOURCE: U.S. Bureau of Labor Statistics, U.S. Department of Labor, 2007

Figure 2.1 Four most frequent work related fatal events, 1992-2006

Out of 5,703 work related fatalities in private US industries in 2006, the transportation and warehousing occupation registered the second highest number of workplace fatalities at 832, second only to construction industries at 1,226 fatalities. Drivers/Sales workers and truck driver occupations accounted for 940 fatalities, with an incident rate of 27.1 fatalities per 100,000 employees. This incident rate is nearly four times the average incident rate of all industries in 2006, which stands at 3.9.

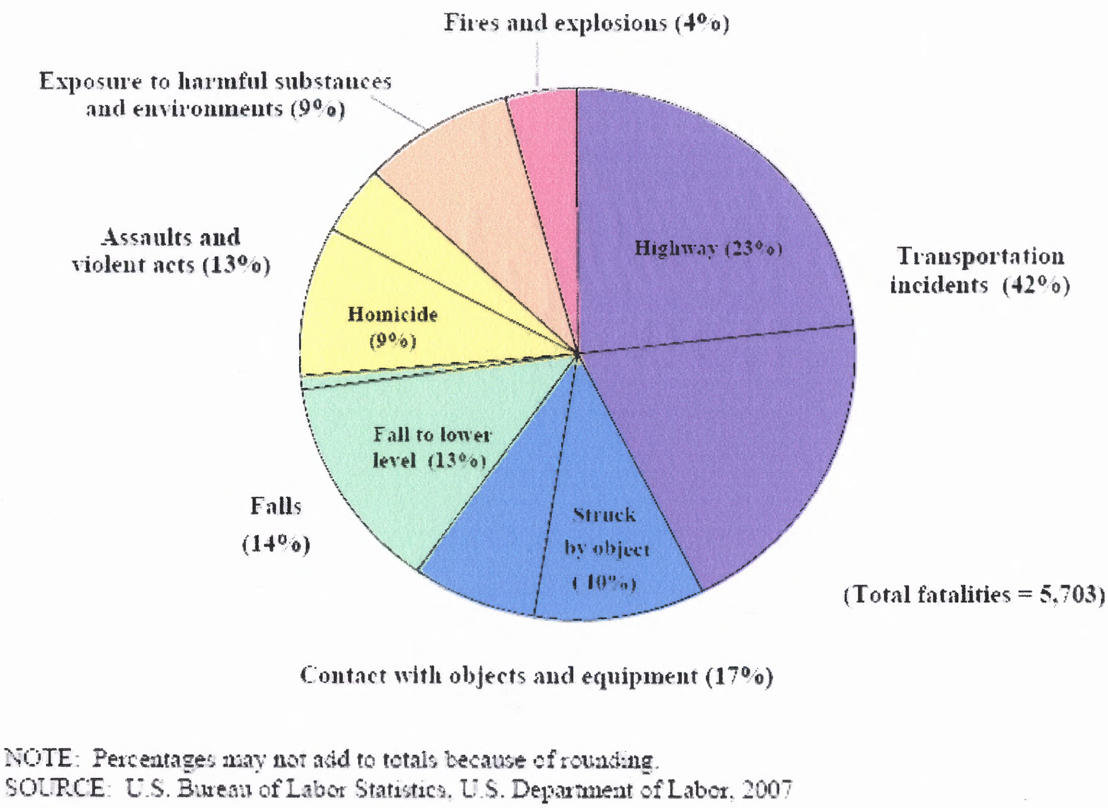
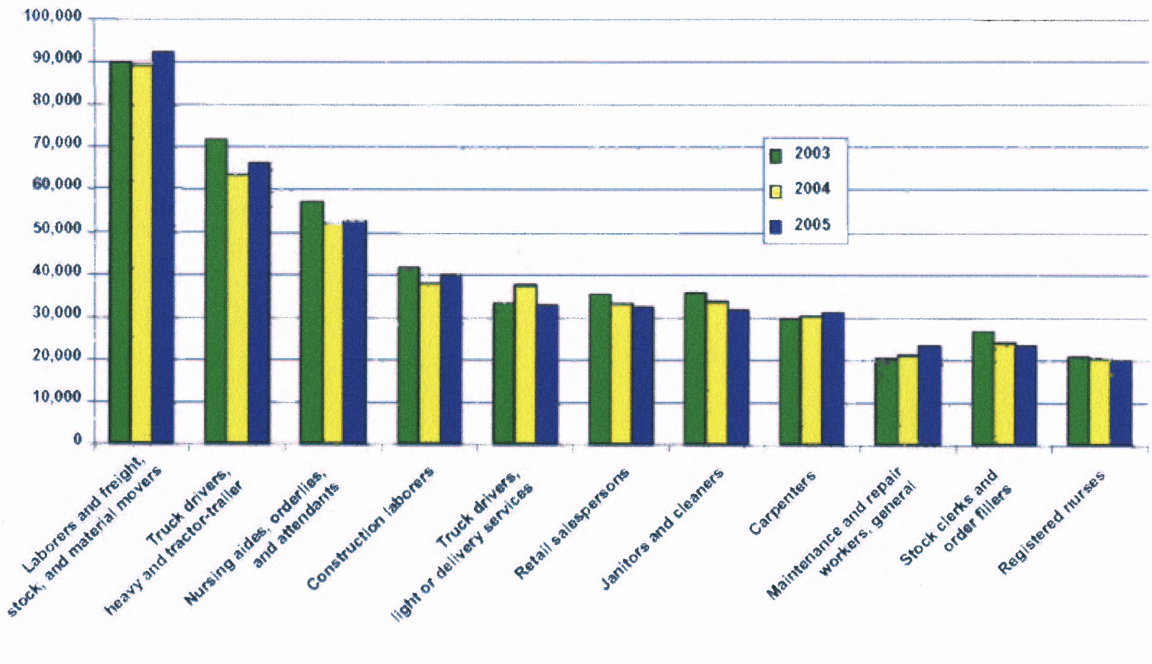


Figure 2.2 Manner in which workplace fatalities occurred, 2006

Statistics related to OSHA recordable, work related non-fatal injuries and illness, that required days away from work also show a similar high rate of incidence for the transportation and warehousing industries. Among the service-providing private industries, transportation and warehousing experienced injuries at highest rate of 7 and 6.5 cases per 100 workers, for the year 2005 and 2006, respectively. In terms of number of non-fatal injury and illness, heavy tractor trailer drivers consistently occupied second highest position, among all other occupational groups (Figure 2.3) for the years 2003, 2004 and 2005. They were only second to the occupational group "Laborers and freight, stock and material movers".

To understand the severity of the injury and illness, Bureau of labor Statistics gathers statistics showing median days away from work per year per incident. The median days away from work were 14 days for heavy tractor trailer drivers, which was highest among all other occupational groups (Figure 2.4).



Source: Bureau of Labor Statistics, U.S. Department of Labor, Survey of Occupational Injuries and Illnesses, cases involving days away from work.

Figure 2.3 Occupations with 20,000 or more injuries and illness, 2003-2005

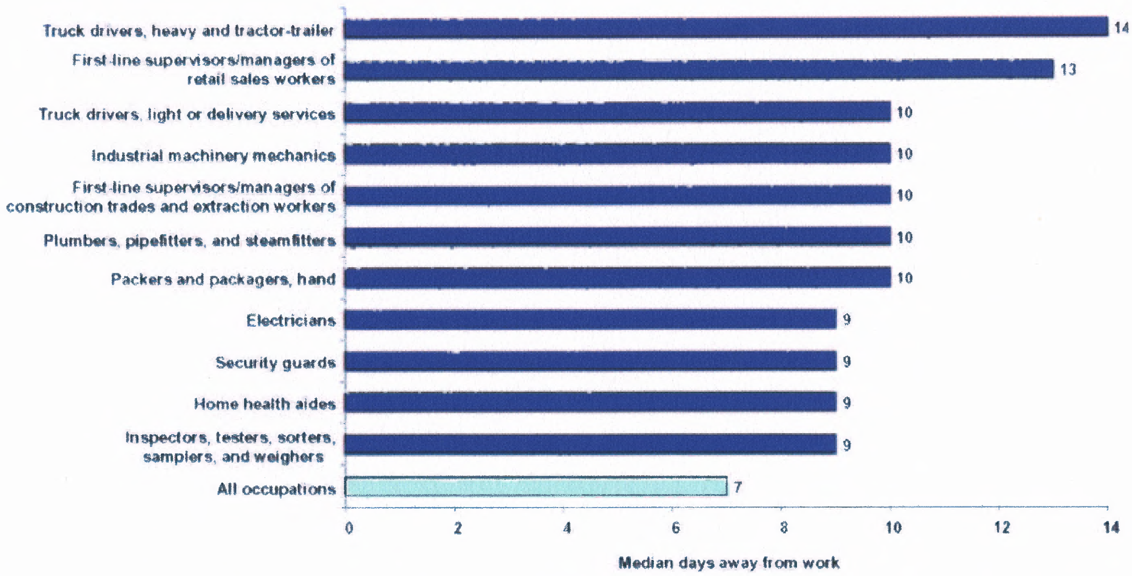


Figure 2.4 Occupations with highest median days away from work due to injury and illness

To estimate occupational risk factors for health problems among truck drivers, Konda et al. (2000) conducted a study by distributing questionnaires regarding working conditions, job tasks in truck transportation, subjective symptoms and present illnesses to 541 truck transportation workers in Japan. The response rate was about 85.7%, and 134 local truck drivers, 199 long-distance truck drivers and 71 clerical workers were analyzed. First, to examine occupational risk factors and health problems among the three groups, the researchers analyzed working conditions, job duties in truck transportation, subjective symptoms and present illnesses. Second, to estimate the work-relatedness of health problems among local truck drivers and long-distance truck drivers, regression analysis was used, and odds ratios at 95% confidence intervals were computed. The prevalence rates of working factors affecting health problems of truck drivers were significantly higher than those of clerical workers in the items on irregular shift work, working environment, working posture, handling heavy materials, job stress due to overloading and long working time and limited time off.

The prevalence rates for subjective symptoms (ringing in the ears, neck pain and low back pain) and present illnesses (hypertension, ulcers in the digestive tract, back injuries, whiplash injuries and hemorrhoids) among truck drivers were also significantly higher than those of clerical workers. In logistic regression analyses, many work-related items except age, body mass index (BMI) and smoking habits showed significantly higher odds ratios for subjective symptoms and present illnesses for truck drivers. Odds ratios for hypertension, heart diseases and related subjective symptoms among local truck drivers were significantly increased by twisting posture, whole-body vibration, and driving stress. Odds ratios for gastro-duodenal diseases and related subjective symptoms were significantly increased by the narrow working space, sleeping in the truck, driving distance, squatting posture, and driving stress. Odds ratios for ringing in the ears among local truck drivers were significantly increased by long working time, narrow working space, sleeping in the truck and driving stress. Odds ratios for musculoskeletal diseases and related subjective symptoms were significantly increased by overwork, vibration, narrow working space, sitting posture and the short length of rests and breaks. Odds ratios for fatigue symptoms were significantly increased by the shortage of recess, vibration and driving stress. As this study suggest, truck drivers are, almost across the board, at greater risk for most major and minor health problems when compared to people in other occupations that do not require prolonged sitting, exposure to whole body vibration, and the provocation of fatigue. To cope with the health problems of truck drivers, it is recommended that working conditions and work loads for truck drivers are improved.

2.2 Fatigue, Sleep Deprivation and Associated Risks

Driver fatigue has been recognized as a probable cause and corresponding risk factor of crashes involving heavy trucks (National Transportation Safety Board, 1995). The need to meet schedules imposes unique challenges on truck drivers compared to other road users; top among these is the task of balancing the need for rest with real or perceived consequences that could arise should drivers fail to maintain the externally imposed schedule demands (Hanowski et al. 1998; McCartt et al.2000). It is well known that economic pressure is often the reason that strongly influences or dictates how delivery schedules will be established, and this often impinges on driver health. The anxiety generated by unexpected delays that disrupt delivery schedules can further intensify if truck drivers and carrier management differ in what they regard as the cause of fatigue in truck drivers (Arnold et al. 1997). In a situation of tight schedules, truck drivers may not feel adequately empowered to stop and rest when the onset of fatigue occurs. The consequences of this behavior, whether self or industry imposed, are more common among long-haul truck drivers than other workers. Several factors, including sleep restrictions and sleep fragmentation, can interfere with truck drivers' ability to obtain the requisite quantity and quality of sleep. Sleep quality can be restricted by work demands, medication, family responsibilities, personal and life style factors (Lyznicki et al. 1998). Sleep fragmentation can affect both the quantity and quality of sleep, as can other common occurrences, including excessive noise and concerns about personal safety while resting in the sleeper berth of a heavy truck. An explanatory study was conducted (Filiatrault et al. 2002) to examine the relationship between sleep quality and how priorities are assigned by commercial drivers when the need to rest interferes with tight delivery schedules. The results showed that lower sleep quality is associated with commercial drivers who place greater emphasis on their real or perceived duty to fulfill externally imposed schedule demands than to refrain from driving in a diminished state of alertness to satisfy the need for rest.

2.3 Hypertension, Cardiac Stress, and Stroke

Backman (1983) and Belkic et al. (1992) showed that there is a significant correlation between being a professional driver and having elevated blood pressure. Workplace hypertension, which is often caused or exacerbated by stress, is common among truck drivers because of the stress and demands of the job. Studies by Backman (1983) and by Yokoyama, et al. (1985) looked specifically at truck drivers' blood pressure (BP) measurements as recorded in clinic settings. More recently, Belkic (2000) reported that among working populations, there is a substantial number of people who have normal BP in the clinic, but high BP while on the job. This phenomenon is called "occult workplace hypertension," and elevates an individual's risk for atherosclerosis, which is an increase in the mass of the left heart ventricle, similar to the people who have persistently elevated BP (Liu, et al. 1999). There is a strong indication that many professional drivers have occult workplace hypertension, given them high risk for developing hypertension.

There is some evidence that cardiovascular disease is also caused in part by truck driving and its risk increases with the duration of this activity and the disruption of the sleep cycle. In a 1998 published review of the literature concerning heart disease risk among professional drivers, Belkic (1996), Van Amelsvoort (1995) and Winkleby et al. (1988) found that professional drivers have an increased risk of hypertension and cardiovascular disease compared to other drivers from the working or general population. It was concluded that such a consistent and large body of data concerning cardiac risk does not appear to exist for any other specific occupational group. It was striking that heart disease often occurred prematurely, to such a degree that professional drivers are over-represented among young patients who had suffered a heart attack. In a paper by Villarem et al. (1982), of 38 consecutive heart attack patients under the age of 30, about 20% were long-route truck drivers. An analysis of disease rates among U.S. workers shows that truck drivers rank among the highest rates of heart attack (Leigh et al. 1997). A study by Gustavsson et al. (1996) showed that after considering age, smoking, and obesity, long distance male truck drivers have a significantly increased risk of heart attack compared to other working men in Sweden.

2.4 Organ Distress and Disease, Chronic and Terminal Illnesses

Lung cancer is likely caused by exposure to diesel exhaust and the longer that exposure lasts the more likely it is that a cancer will develop. Though the evidence linking this exposure to bladder cancer is less robust than that to lung cancer, it remains likely that there is such a relationship. Cigarette smoking is also very common among truck drivers. In a survey conducted by Nelson and colleagues (1994), data from the National Health Interview were used to assess smoking prevalence in over 200 occupations in the U.S. In 1987-1990, drivers of heavy trucks were among the 20 occupations with the highest smoking prevalence; a total of 45.8% of drivers of heavy trucks were current cigarette smokers.

2.5 Obesity

Several studies have reported that professional drivers are more obese than workers in other occupations. Hedberg et al (1993) reported a significantly greater mean body mass index of 26.3 among a group of bus and truck drivers, compared to 25.9 among working people of other occupations.

In a study of sleep amongst truck drivers, Moreno et al (2006) concluded that short sleep duration is associated with obesity in truck drivers because they frequently work irregular shifts. In addition, truck drivers have a high prevalence of sedentary habits and poor diet. The study sample consisted in 4,878 truck drivers who participated in a campaign promoted by a highway company in the State of São Paulo, Brazil.

2.6 Musculoskeletal Disorders

Bureau of Labor Statistics (2006) data on injury and illness show that the drivers of heavy trucks and tractor-trailers in the US are associated with second highest number of occupational illnesses and injuries for the past three years (Figure 3). Using the Bureau of Labor Statistic (2007) database, a statistical report has been compiled to understand the characteristics of these injuries/illnesses in the long distance freight trucking industry. The detailed statistical report can be found in Appendix A. The report is based on the statistics of incident rates of injuries/illnesses. Incidence rates represent the number of injuries and illnesses per 10,000 full-time workers and were calculated as: (N / EH) X 20,000,000 where, N = number of injuries and illnesses, EH = total hours worked by all employees during the calendar year, and 20,000,000 = base for 10,000 full-time equivalent workers, working 40 hours per week, 50 weeks per year. Thus the incident rates provide measures of propensity for incidents, irrespective of the size of the industry whereas the number of incidents are influenced by the size of the industry.

The injury and illness incident rates of the long distance trucking industry were consistently two to three times higher for every year from 2003 to 2006 when compared to overall incident rates in the US private sector industries. The average incident rates of all United States private industries for 2006 was 127.8, as opposed to 351.6, 301.2, 315.5, and 279.8 for the years 2003, 04, 05, and 06, respectively for the long distance trucking industry.

Backman, (1983) and Hedberg (1988) pointed out the high prevalence of musculoskeletal disorders (MSD) among professional drivers. Lower back pain is very common, and has been closely related to exposure to vibration and prolonged seating. The statistics of incident rates related to MSD for the long distance trucking industry in the US confirms these findings. Table 2.1 shows excerpts of the incident rates of injury and illness related to MSD for the long distance trucking industry. Data for years 2003-2006 show that the sprain-strain, soreness and back pain in this industry had two to three times the incident rates compared to the average for the US private industries. When the incident rates were compared with those of the average US private industries, the most frequently affected body regions were neck, back, shoulder, wrist, knee and foot. Worker motion and position as the source of injury was also two times higher when compared to the average industry scores. Worker motion and position are related to working posture, and these incidents are classified as injuries related to working posture. Furthermore, over exertion and over exertion during lifting were twice as common for employees of the long distance trucking industry.

Table 2.1 Injury and illness incident rates for long distance freight trucking industry compared with overall private industry incident rates (Source: Bureau of Labor Statistics, 2007)

Characteristic	Private industry	General Freight Trucking, Long-Distance			
	2006	2003	2004	2005	2006
Total injury/illness	127.8	351.6	301.2	315.5	279.8
Nature of injury, illness:					
Sprains, strains	51.1	170.1	149.1	159.9	131.8
Soreness, Pain	11.3	24.6	18.2	26.3	15.2
Back pain	3.8	8.7	5.9	12.1	6
Part of body affected:					
Neck	1.9	7.5	7.8	5.7	8.4
Back	27.1	78.2	64.4	80.3	55
Shoulder	8.2	30.4	28.5	28.2	26.7
Wrist	5.3	14.3	10.4	7.4	10.9
Knee	10.3	29.9	21.7	28.7	23.3
Foot, toe	6.2	13.4	12.3	13.5	12
Source of injury, illness:					
Worker motion or position	17.6	47.3	35.3	38	33.6
Event or exposure:					
Overexertion	30.8	77.3	75	86	66.9
Overexertion in lifting	16.3	27.9	27.3	33.7	21.5

In the study by Magnusson et al (1996), back and neck pain among urban transit operators was significantly related to ergonomics, such as poor seat adjustment, steering and braking problems, as well as long, uninterrupted hours behind the wheel. (Urban transit operators have similar work conditions like truck drivers) Stressors are exacerbated by high psychological demands. In order to handle a heavy truck and control the large steering wheel, drivers must sit in a rigid, upright position that, if held for long periods of time, leads to stiffening of the neck, back, and muscles of the extremities. These problems will be explored in greater detail in the following chapters.

Whole-body vibration (WBV) is one of the most significant risk factors for lower back disorders (NIOSH, 1997), and is also considered the most common and costly occupational injury in industrialized countries (Fry Moyer et al. 1991; Webster et al. 1990). Whole body vibration (WBV) is the most common vibratory exposure in occupational life and, regarding back problems, probably the most hazardous (Seidel et al. 1986). Additionally, drivers are exposed to other activities, such as loading and unloading a truck and prolonged sitting, which are believed to be harmful to the spine. Several studies have shown a significant risk for back problems from WBV alone (Fry Moyer et al. 1980, Kelsey et al. 1980, and Troup et al. 1978). Epidemiological studies have frequently indicated an elevated health risk for the spine in workers exposed for many years to intense whole-body vibration, especially those who work on tractors or earth-moving machines and who have jobs that involved prolonged periods of sitting (Bongers et al. 1990; Dupius et al. 1987). Bovenzi et al (1992) measured WBV exposure in bus drivers and investigated the prevalence of lower back pain (LBP) using a questionnaire. They learned that LBP increased with WBV exposure in terms of lifetime vibration dose and herniated nucleus pulposus in drivers with the most severe WBV exposure (long-term exposure).

In an experiment using animal subjects, Holme (1977) substantiated that WBV leads to poorer disc nutrition and consequently to an accumulation of metabolites. The accumulation of metabolites is believed to stimulate the degenerative process of the disc The prevalence of spinal disorders was found to be higher among experienced bus drivers compared with control subjects in a prospective longitudinal study by Gruber et al. (1974) and in a later lone study by Gruber (1977), who found a high incidence of early degenerative changes of the spine of truck drivers. In a study conducted several years earlier, Fishbein et al. (1950) also identified a positive relationship between truck driving and various spinal disorders.

2.7 Occupational Risk Factors

From the study of the occupational health status of the trucking industry, two distinct and major risk factors related to this occupation turn up as root causes. The first one is the effect of prolonged seating and whole body vibration which are characteristics for this occupation and are believed to be the main risk factors for musculoskeletal disorders (MSD) particularly back pain. The second root cause is the mental fatigue, which is caused by long, irregular working hours and stress related to driving, which is believed to have strong influence on causation of accidents and poor mental and physical health. The following two chapters concentrate solely on the mechanism by which prolonged sitting and whole-body vibration contributed to adverse health effects, and factors that influence fatigue in the truck driving occupation.

The methodology employed to achieve the objective is a meta-analysis of seminal and recent research literature. Building upon the topics explored in the literature review, the following two chapters delve more deeply into the specific causes and outcomes of these particular ailments, and begin to establish a locus around which recommendations and best practices for truck driver health can be developed in later chapters. The justification for the methodology is pragmatic. Because there is a rich body of existing data on the subject of truck driver health that has not been evaluated and mined, it makes sense for the researcher to utilize these data and interpret them. Secondly, because the researcher does not have access to a sample of truck drivers, nor the medical expertise to evaluate the conditions being studied here, it is impractical to propose a methodology to achieve such an aim. Rather, it is the goal of the researcher to build upon existing studies by integrating the findings and knowledge that they offer and, in doing so, develop a set of original recommendations that can be implemented by trucking companies and by drivers themselves to improve driver health.

CHAPTER 3

PROLONGED SITTING AND WHOLE BODY VIBRATION

3.1 Prolonged Sitting

If a truck or car is not moving, then sitting in a driving seat is not significantly different than sitting in a padded chair. As soon as the vehicle starts moving, however, conditions change dramatically. Unlike regular sitting, while a vehicle is in motion the body is subject to different forces of acceleration and deceleration, lateral swaying from side to side, and whole-body up and down vibrations. When driving, the feet are being used actively, moving from the fuel pedal to the brake, and in a stick-shift vehicle, the left foot manages the clutch. When the feet are active they cannot be used to support and stabilize the lower body as normally happens when they are placed on the floor during normal sitting in a chair. Additionally, the driver must maintain a vigilant watch for traffic all the time, which requires a fairly static head and neck posture. To maintain this steady driving posture, internally the back, neck, shoulder and arm muscles maintain a static muscle tension over a prolonged period of time. A steady low level muscle contraction can lead to localized muscle fatigue (Konz et al 1998), which produces muscle aches and pains.

3.1.1 Physiology of Muscle Fatigue and Pain

To produce muscle contraction, a muscle metabolizes energy molecules derived from food in the form of nutrients. Within the muscle cells, the nutrients are converted to mechanical energy in the form of muscle contractile force. In the presence of oxygen, the metabolic reaction occurs through an aerobic process. Aerobic energy production is efficient, in the sense that complex nutrient molecules are broken down to more elementary molecules releasing a greater amount of energy per nutrient molecule. The metabolic end products for the aerobic metabolism are carbon dioxide and water. When the oxygen supply is inadequate, the cell can supplement energy production through an anaerobic pathway, which metabolizes the nutrient molecules to an intermediate stage. Thus the anaerobic metabolic process produces less energy per nutrient molecule. But, more important is the fact, that the intermediate molecules produce lactic acid, which when accumulated to a certain level of concentration, produces a localized sensation of muscle pain, known as localized muscle fatigue. (Sjogaard et al. 1986)

Blood acts as a medium for carrying in and out oxygen, nutrients, and metabolic waste products from the muscle cells, which are perfused with blood from the nearby capillaries. During muscle contraction, a force develops within the muscle tissue that increases intramuscular pressure. When the intramuscular pressure is more than the capillary closing pressure (>30 mm Hg), the blood flow in the nearby capillaries stops. It has been shown, that the blood flow restriction starts at as low as at 10% and is completely restricted at a 50% level of a muscle's maximum force capacity (Sjogaard et al. 1986). Restriction of blood flow gives rise to anaerobic metabolism and increases the concentration of lactic acid.

The extent of muscle ischemia (lack of oxygen) and concentration level of lactic acid accumulation depends on the type of muscle work (dynamic or static) and the force level of muscle contraction. In a dynamic type of muscular work, muscle contraction is interspaced by muscle relaxation. Any muscular work, which causes movement of the body limbs, is an example of dynamic muscular work. In this type of work, during the muscle relaxation phase, intramuscular pressure diminishes and blood flow to the muscle is re-established and replenishes the oxygen stored in the muscles, and then carries away the metabolite waste products.

Static muscular work requires muscle tension to be maintained continuously, without intermittent muscle relaxation. This type of muscle contraction is mostly involved to counter the gravitational forces that are acting on body segments. For example, when a driver is constantly watching the road, the neck muscles are constantly acting to hold the head (average weight 14 pounds) in a fixed position. To maintain a driver's fixed driving posture, muscles at the shoulder, neck, back, and the lower extremities, are at a continuous contractile state for a prolonged period of time.

The relationship between level of static muscle tension and endurance time to reach fatigued can be assessed by the well known Rohmert's model (Chaffin et al. 2006). The model predicts that muscles can maintain sustained or static tension indefinitely when the level of tension is below 15% of the muscle's maximum force generation capacity. More recent studies (Chaffin et al. 2006) indicate that muscle fatigue and pain can develop at much lower muscle contraction levels (Sato et al. 1986). This model indicates that even at less than 5 percent of muscle maximum capacity, muscle fatigue and pain can develop if the tension is sustained for a prolonged period of time (between 1000 and 10000 seconds).

Ischemia due to static contraction and accumulation of lactic acid is hypothesized to bring localized muscle fatigue. While the fatigued cells are not themselves permanently damaged, reperfusion after ischemia in muscle cells lead to micro-vascular and cellular dysfunctions, initiating longer-term symptoms and functional changes in skeletal muscle (National Research Council and Institute of Medicine, 2001). Static contractions at low level over a prolonged period of time can cause muscle to atrophy, splitting, necrosis and other degeneration, which in tern precipitate as chronic muscle pain and discomfort, even when the static muscle forces are not present.

3.1.2 Sitting and Low Back Pain

Figure 3.1 shows a radiograph of lumbar spine in standing position, with a normal lordosis curve of the spine at the lumbar region. Radiographic data shows that the pelvis rotates backwards and the lumbar spine flattens when one is sitting down in a relaxed posture (Chaffin et al. 2006). This change in curvature is believed to reduce the load bearing capacity of the lumbar spine and puts the structure at higher strains during sitting.

The research literature is divided with respect to making a decisive determination about whether it is better to sit with a flattened or an arched back. Some experts have argued that sitting with flattened back results in increased nutrition to the discs and less load on the posterior lumbar discs, where people often experience spinal problems. On the other hand, there are researchers, including Adams et al (1985), who argue that flexed postures are advantageous compared to the flat-back position, since flexion results in increased fluid flow and improved transport of nutrients into the inter vertebral discs. This argument posits or shows that the likelihood of degenerative changes may be decreased, which is important, as such degeneration has been linked with decreased metabolic transport in the lumbar.

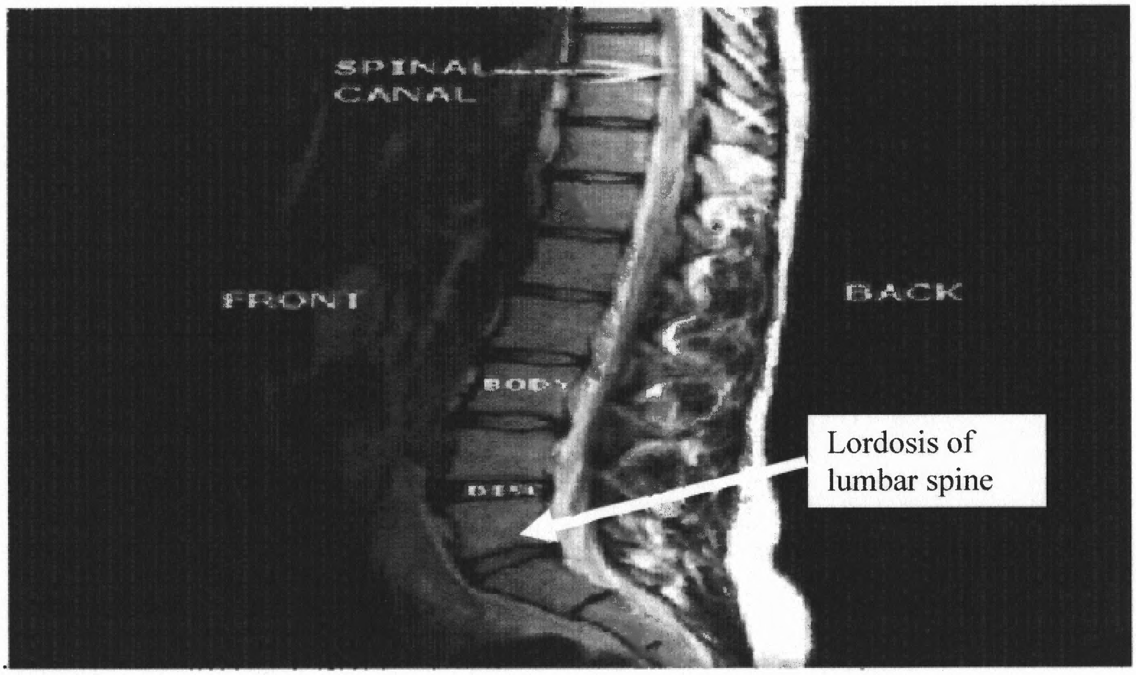


Figure 3.1 Lumbar spine in standing position
(Source: American academy of orthopedic surgeons 2002)

The intervertebral discs have an incompressible gel like structure, called nucleus, which is contained within a strong elastic wall of fibrous tissue. This structure permits efficient load distribution to the vertebral bodies. Due to lack of vascularity, disc nutrition is achieved by diffusion only. When the load on the disc increases, fluid flows out of it and when the load on the disc is decreased fluid flows into it. Prolonged sitting is associated with constant spinal pressure and hence can impede disc nutrition and consequently cause disc degeneration (National Research Council and the Institute of Medicine, 2001). Research has also shown that lumbar disc herniation may result from prolonged sitting in the typical flexed posture. This is especially the case if sitting occurs in motor vehicles where the vibration forces add to the stress on the discs, as it does in commercial heavy equipment driving.

Prolonged sitting causes other spinal vulnerabilities as well. Ligaments in the back help to hold the spine together as one move. These ligaments will stretch and slacken if a person is sitting down for a long time. After standing up, the ligaments remain slack for a while, and cannot support the spine as they normally do.

If the seat is not adjusted correctly, pressure points can be developed in the buttocks and back of the thighs, causing muscle strain in the lower back. If there is vibration during this period, upper back and neck muscles of truck drivers are required to hold the head in position, there by causing continuous muscle activities, which can then lead to muscle strain. Holding the foot over the pedal continually and over an extended period, may also cause stiffness and spasms in the legs and lower back (Konz et al 1998).

Drivers are encouraged to make stops as required by law to help stretch their muscles and support electrolyte and fluid balance that improves the circulation of blood, thereby preventing blood pooling. Maintenance of the same posture over a long period with continued muscle tension becomes uncomfortable, and can cause health problems. When sitting, the curve of the spine changes and pressure is applied in different parts of the spine. Prolonged sitting intensifies that pressure, leading to back problems, especially for truck drivers.

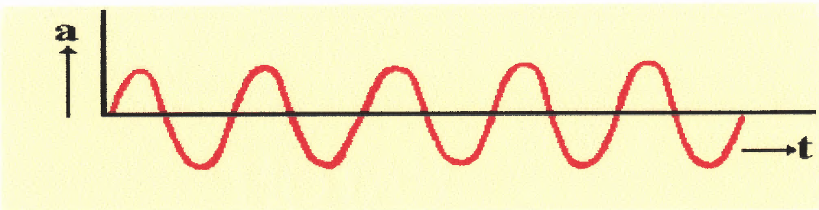
3.2 Whole Body Vibration

The effects of vibration and physical shock on human beings have been known for a long time, and possibly as much as two centuries ago. When power tools were introduced in the early 1900s, for instance, operators started to experience vascular disorders in their fingers and hands involving some impairment of circulation and blanching of fingers. This condition was called Raynauld's phenomenon, traumatic vasospastic disease (TVD), white finger (WF), or most commonly, vibration-induced white finger (VWF). The condition was first noticed among stonemasons, whose work during this period involved the transition from "old" tools of mallets and hammers, to new tools like pneumatic drills and air hammers. Similarly, the introduction of chainsaws to the timber industry, led to loggers being at risk of vibration-related diseases and ailments. Since then, many other professions have been identified as "high risk" occupations, among them operators of pneumatic, electrical, and diesel hand tools, drivers of trucks, buses and heavy equipment. Every day, people are exposed to vibrations from many sources, including vehicles and vibrating machines, as indicated above. Most people have a good idea of what vibration feels like, but not necessarily what vibration is or what kinds of physical consequences it can have.

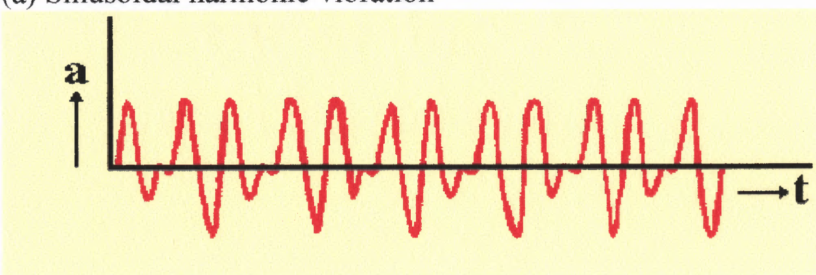
3.2.1 Types of Vibration

Vibration is the oscillation of a mass about a fixed point. In the human body, vibrations are produced by either regular or irregular periodic movements of a tool or vehicle, or other mechanisms that come in contact with a human and which displace the body from its resting position. If the human body were on a rigid bulk of mass, in translation all parts would undergo the same motion. Vibration can be divided into the following types: Harmonic and Periodic Vibration, Random Vibration, and Transient Vibration.

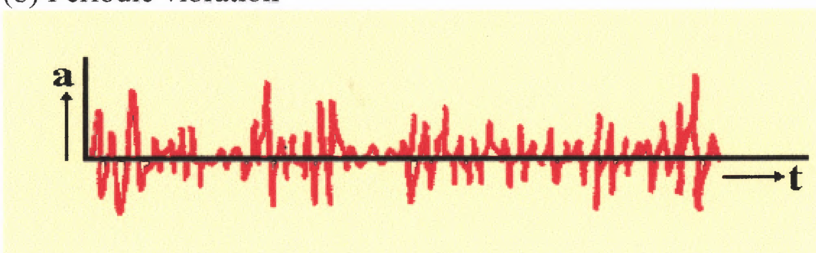
Vibration that is comprised of one (Figure 3.2a) or several sinusoidal components (Figure 3.2b) is called harmonic or periodic vibration, and repeats itself over time. One type of periodic vibration is that caused by out of balance tires on a road vehicle. Figure 3.2 (a) and (b) show the amplitude "a," which is varying periodically with time "t" in a sinusoidal harmonic vibration. Figure 3.2(b) represents a periodic vibration, which is a combination of two harmonic components. Vibration that does not repeat itself continuously is called random vibration, which is depicted in Figure 3.2(c). This type of vibration is what one experiences when driving a car on a bumpy road. Vibration that is of a short duration and is caused by mechanical shock is called transient vibration, which is represented in Figure 3.2(d). Transient vibration occurs when a vehicle hits a pothole.



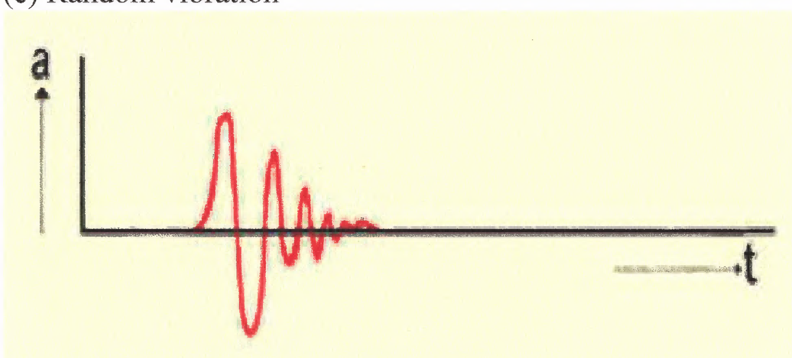
(a) Sinusoidal harmonic vibration



(b) Periodic vibration



(c) Random vibration



(d) Transient vibration

Figure 3.2 Types of vibrations

In practice, drivers of all types, whether private or commercial, short-haul or long haul, tend to experience a combination of harmonic, random and transient vibrations. Whole body vibration is injurious to the body, regardless of the type of vibration. For truck drivers, the dangers of whole-body vibration are more serious than for other populations because the variety, frequency, and intensity of vibrations are generally higher than those general public experiences. Whole body vibration is generated by a system that accelerates the body in a motion.

3.2.2 Understanding Whole Body Vibration

To understand whole body vibration, the following points needs to be closely observed.

1) Paying attention to the point of the vibration's application to the body: Three points at which vibration enters the body are significant ergonomically: the buttocks, the feet (when driving or riding in a vehicle), and the hands (when operating hand tools, steering wheels, and machines).

2) Observing the direction of application: The direction of oscillation is important. For the main part of the body, especially the trunk/torso region, the direction of oscillation mostly lays in the vertical plane (head to foot). For the hand and arm, the direction of oscillation is often approximately perpendicular to the line through the hand and arm.

3) Observing the frequency of oscillation: The extent of the biomechanical effects of vibration is strongly dependent upon the frequency with which such effects are experienced. Particularly important frequencies are those which fall into the range of natural frequencies of the body and cause resonance. Vibrations of motor vehicles are of the low type.

4) Noting the acceleration of oscillations: Within the frequency range that is physiologically important, the acceleration of the oscillation is usually taken as a measure of the vibration load.

5) Recording the duration of vibration: The effect of vibrations depends greatly on the duration.

6) Determining the degree of resonance: Every mechanical system that possesses the elementary properties of mass and elasticity is capable of being set in oscillation. Each

system has its own natural frequency at which it vibrates after stimulation. The nearer the frequency of the inducing force comes to this, the greater will be the amplitude of the forced vibrations. When the amplitude of the forced vibrations exceeds that of the inducing force, the system is said to be in resonance

7) Determining the extent of damping: The oscillations of any system are subject to damping, which reduces the amplitude. Thus, for example, when we are standing up, any vertical vibrations transmitted at the feet are quickly dampened in the legs.

Vibration is dangerous, and as such, different systems of the body attempt to absorb some of the shock to reduce deleterious effects on a single organ or system. The distributive impact of the vibration, then, may affect the whole body, as opposed to just the zone that would otherwise be targeted if the rest of the body did not play this absorptive function. Above the frequency of 2 Hz, the human body does not vibrate as a single mass with one natural frequency; rather, it reacts to induced vibration as a set of linked masses. Studies have shown that the natural frequencies are different in different parts of the body.

3.2.3 Measurement of Whole Body Vibration

Vibration experienced at work has been measured mainly among employees who work with construction machinery, tractors, trucks, and cars. The studies on various motor vehicle operators have revealed that the acceleration of vertical oscillations lies between 0.5 and $5 m/s^2$, with the highest values being recorded for earth moving machines and tractors. Bumps on the road cause up-and-down vibration of the vehicle or truck frame along the length of the spine.

Vibration is characterized by magnitude, frequency, duration, and direction. The magnitude is how powerful the vibration is. The number of complete cycles that occur per second is called the frequency of the vibration and is measured in hertz. Human responses to vibration increase with duration of exposure, so it is important to define a dose measure, which incorporates the exposure time factor. To determine the effective daily exposure it is necessary to gather information on the number of minutes or hours per day when exposure to vibration occurs. The long driving time of truck drivers is an indication of long exposure to whole body vibration.

Measuring the vibration entering the body assesses the exposure of the human body to vibration. The vibration can be measured along three perpendicular directions (Figure 3.3). If there is more than one point at which vibration enters the body, there will be more than one coordinate system for obtaining measurements. In human vibration, a biodynamic set of axes is used with the point of contact as the origin of the coordinate system. The directions, according to ISO 2631-1 (1997.) are: x, back-to-front; y, right-left; and z, foot-head (Figure 3.3).

Whole-body vibration should be measured at the interfaces between the body and the source of vibration. For seated persons, this measurement, involves the placement of accelerometers on the seat surface beneath the ischial tuberosities of the persons to be measured. Vibration is also sometimes measured at the seat back (between the backrest and the back), and at the feet and hands.

Epidemiological data alone are not sufficient to define how to evaluate whole-body vibration in order to predict the relative risks to health from the different types of vibration exposure. A consideration of epidemiological data in combination with an understanding of biodynamic responses and subjective responses is used to provide a comprehensive approach. The manner in which health is affected by oscillatory motions depends upon the frequency, direction, and duration of motion, which is currently assumed to be the same as, or similar to, that for vibration discomfort. However, it is assumed that the total exposure, rather than the average exposure, is important, and so a dose measure is appropriate. In addition to evaluating the measured vibration according to current standards, it is advisable to report the frequency spectra, magnitudes in different axes, and other characteristics of the exposure, including the daily and lifetime exposure durations.

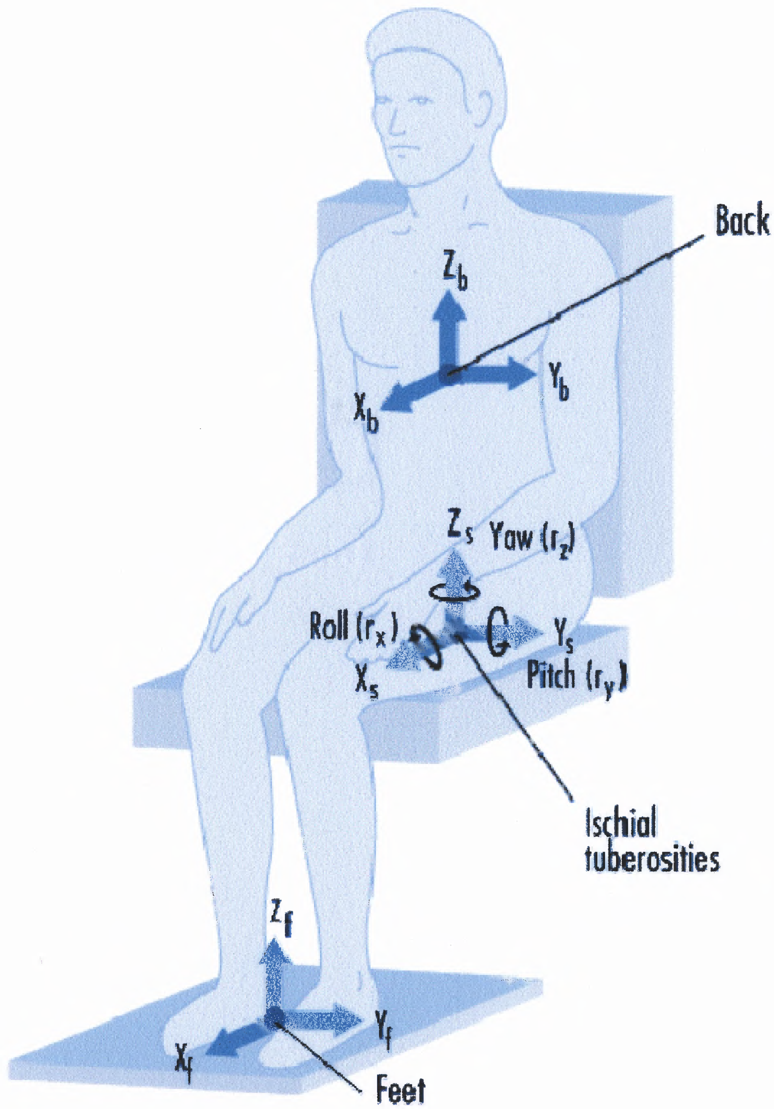


Figure 3.3 Axes for measuring vibration exposure of seated person
(Source Safety line 2007)

3.2.4 Whole Body Vibration Effects on the Health of Truck Drivers

The health effects of whole body vibration vary considerably. Other factors such as ergonomic design, damping, and resonance have a great effect on the exposure characteristics and intensity levels of vibration exposure experienced by drivers. The main problem is caused by the vibration energy waves, much the same as noise, which are transferred from the energy source, such as the vehicle, onto the body of the exposed driver and then transmitted through the body tissues, organs, and systems causing various effects on the structures within the body before the vibration is dampened and dissipates. The risk of illness depends on the characteristics of vibration, namely magnitude, frequency, duration, and direction.

The period the drivers sits behind the wheel driving, is a reasonable time of exposure to whole body vibration. This vibration has many more widespread and varied effects; though the effects may not be felt by the individual, but they are registered and recorded by the body. Bovenzi (1992) linked low back pain to WBV in his study of low back pain and exposure to WBV in bus and tractor-trailer operators. The result of that study indicated that professional truck drivers were at a greater risk of developing low back pain, which is caused by various mechanisms of vibration on the musculoskeletal system of the body, namely the degeneration of the inter vertebral discs, which leads to an impairment of the mechanics of the vertebral column, thereby allowing tissues and nerves to be strained and pinched. The nutrition of the discs is also affected by long periods of sitting aggravated by vibration exposure, which causes tissue nutrients needed for growth and repair of the discs to flow out of the discs by diffusion instead of inwards where they are required. This leads to increased wear and reduced repair of the discs. The vertebral bodies are also damaged by the vibration energy that leads to an accumulation of micro fractures at the end plates of the vertebral bodies and associated pain.

Muscle fatigue also occurs as the muscles try to react to the vibration energy to maintain balance and protect and support the spinal column, but these are often too slow as the muscular and nervous systems cannot react fast enough to the vibration shocks and loads being applied to the body. During active natural motion, motor control mechanisms act as a feed-forward control that are constantly adjusted by additional feedback from sensors in muscles, tendons, and joints. Whole-body vibration causes a passive artificial motion of the human body, a condition that is fundamentally different from the self-induced vibration caused by locomotion.

In several cross-sectional studies, Bongers et al (1990) found more lower-back pain in drivers and helicopter pilots than in workers in comparable professions, the studies concluded that professional vehicle driving and helicopter flying are important risk factors for lower back problems because they involve long hours of continuous restriction of the legs and back muscles.

Other health effects that have been associated with whole-body vibration, and especially the driving environment, are hemorrhage, high blood pressure, kidney disorders and impotence. A literature review by Thalheimer (1996) indicated exposure to whole body vibration may affect the cardiovascular, cardiopulmonary, metabolic, endocrinologic, nervous and gastrointestinal systems of the body.

CHAPTER 4

DRIVER FATIGUE

Fatigue is a manifestation of stress and a subjectively experienced disinclination to continue performing the task at hand and certainly indicates the existence of a problem (Hancock et al. 2001). For long-haul drivers in particular, fatigue is a serious matter with implications for their own safety and the well-being of others. The definition of fatigue is difficult to determine precisely, as it is somewhat subjective and varies from one person to another. However, researchers have defined fatigue based upon its effects.

Fatigue can be classified into three distinct types: physical, mental, and chronic. The following is a brief description of these types of fatigue, and the ways in which they can affect a truck driver.

Physical Fatigue: Symptoms may include:

- A temporary loss of muscle power to respond to demands
- A feeling of tiredness, soreness, or discomfort
- Physical performance declines

Mental Fatigue: Symptoms may include:

- A feeling of tiredness after extended or repeated tasks, particularly non-physical tasks, such as driving
- A feeling of monotony or boredom caused by lack of varied stimulation.

Mental fatigue negatively affects one's level of alertness at the wheel and leads to poor driving performance.

Chronic Fatigue: Symptoms may include:

- A feeling of persistent tiredness, soreness, or discomfort
- A feeling of persistent monotony or boredom caused by lack of varied stimulation
- The inability to feel refreshed after a brief rest period.

Chronic fatigue is of particular concern for long-haul truck drivers, as it results from repeated and cumulative stresses. Though its name suggests otherwise, chronic fatigue is a short-term condition that can be relieved by adequate rest and sleep. Usually, a driver can recover full alertness in just a few days with longer periods of sleep. Drivers' physiological behavior patterns repeat daily in synchronization with their internal biological clock. Sleeping, working, and eating meals on a new schedule require a period of time to adjust.

Most truck drivers drive for long hours, which mean sitting in one place for a long period of time, and this subject the body to stress, due to poor blood circulation in lower limbs and static muscular contraction. Long driving hours, according to the National Transportation Safety Board, include time on the wheel in excess of 10 hours, combined with limited and insufficient rest hours. Driver fatigue is an important safety issue facing the road transport industry, and the most dangerous aspect of driver fatigue is tiredness and falling asleep at the wheel. Research studies indicate that driver fatigue is a major factor in highway collisions involving heavy vehicles (Pack et al. 1995). Research has determined that working time, evening work, and inadequate periods of rest play a role in driver fatigue (De Castro, 2004; Federal Motor Carrier Safety Administration, 1995.).

Data from studies conducted in the U.S. and abroad indicate that driver sleepiness plays an important role in road accidents. Since 1939, United States federal law has placed restrictions on the "hours of service" that a trucker may operate his truck.

Recently, changes have been made to these rules for the first time in over 60 years. The rules are designed to promote safety by helping to ensure that truck drivers are getting the needed rest to operate trucks safely. However, both drivers and their superiors are often lax in terms of abiding by and enforcing the rules.

In a 1992 *Journal of Public Health Policy* article, "Long Hours and Fatigue: A Survey of Tractor-Trailer Drivers," a team of six investigators reported on interviews they had conducted with 1,249 semi-trailer drivers at inspection stations and truck stops in Connecticut, Florida, Oklahoma, and Oregon (Braver et al.1992). The investigators found 31% (386) of the drivers admitted having driven more than the weekly hours-of-service limit of 60 hours over seven days or 70 hours over eight days. Another six percent of the drivers reported they had not violated the hours-of-service law during the current month, but had done so during the previous month. In addition, 19% of the drivers stated they had fallen asleep at the wheel one or more times during the past month, and two-thirds acknowledged having under-reported their actual hours of work in their logbook during the previous year. Falsification of logs is, in fact, so common, and verification of log entries so difficult for United States Department of Transportation officials that truckers dismiss the log as not very important.

In addition to federal laws governing truck drivers' schedules, various states impose their local laws as well. In New Jersey, for instance, drowsy driving has been criminalized as a means of demonstrating the government's interest in keeping highways safe (Maggie's law N.J.S.A. 2C: 11-5). Many long-haul drivers face chronic partial sleep deprivation. A study of 80 long-haul drivers over a five-day period found that their electro physiologically verified sleep averaged 4.78 hours per day (and only 3.83 hours of sleep per day for those drivers on a steady night schedule) (Mitler et al. 1997). There are serious adverse health effects of this sleep deprivation that may not be immediately obvious to the driver.

One such study was conducted in Peru (De Castro et al. 2004). Using a supervised, pre-tested survey, a cross-sectional observational and comparative study was carried out with 238 bus drivers who drive on the Northern Pan American Highway. To determine the relationship between variables the chi-square test was used, along with the Pearson correlation coefficient. The variables analyzed were tiredness, sleepiness, hours of driving per day, daily hours of sleep, body mass index, snoring, sleep apnea, and either having had or almost having had an accident while driving. Of the 238 male drivers who participated in the study, 45% said they had had or nearly had an accident while driving, 55% slept fewer than six hours per day, 31% had slept fewer than six hours in the 24 hours before answering the survey, and 80% were in the habit of driving more than five hours without stopping. In addition, 56% of the drivers reported being tired at least some of the time while driving, and 65% of them reported being tired during the early morning. Seventy-six drivers (32%) said that while they were driving their eyes had closed. In terms of where they slept, 194 of the drivers (81%) said they always slept in the lower luggage compartment of the bus while another driver was driving the bus or when the bus was parked in the bus terminal. The steps that drivers took to avoid falling asleep while driving included wetting the face with water, eating fruit, opening the window of the driver's compartment, drinking coffee, listening to music, smoking, chewing coca leaves, and drinking alcohol mixed with coca leaves. Obviously, some of these strategies pose an entirely different yet equally dangerous set of health risk factors, both for the driver, for passengers, and for the general public. In the opinion of 55% of the drivers, the leading cause of road accidents is tiredness. Accidents and near-accidents while driving occurred mainly between midnight and 6:00 A.M. The authors of the study concluded that having an accident or a near-accident was strongly associated with tiredness and with having the eyes drop shut while driving.

Tiredness and sleepiness while driving were common among bus drivers in the Peruvian study, with various possible causes, including acute and chronic sleep deprivation, irregular schedule changes, and sleep disorders due to the drivers' working conditions. The results support the hypothesis that fatigue and sleepiness among bus drivers are related to road accidents. The same is likely to be true of truck drivers.

Fatigue in truck drivers has been associated with an increase in the likelihood of becoming involved in a road traffic accident. Other factors, such as ongoing pain and the use of alcohol or illegal drugs, also influence accident rates, but fatigue is considered among the most serious of the identified risk factors. A relatively high risk of becoming involved in a road traffic accident prevails when drivers are on the road not observing their normal sleep time, and/or when working long hours.

Working long hours, not getting enough sleep, or having disrupted sleep, are all prime contributors to fatigue, which will without a doubt, decrease an individual's performance.

4.1 Determinants of Fatigue

Fatigue is a joint function of the nature of the task in question, the person's ability and motivation to perform that task satisfactorily under normal conditions, the perceived consequences of failing to perform the task satisfactorily, under adverse conditions, and the provisions made to relieve the individual of responsibility of the task when its condition of satisfactory performance is in doubt. Three main factors determine if humans can continue performing work in the long term. The length of continuous work and daily duty periods, the time that is made available and utilized for rest and the arrangement of duty and rest and sleep within each 24-hour period of day light and darkness, which normally is associated with individuals circadian rhythms. For drivers who work shifts for irregular hours over extended period of time, the effects of the three factors are interdependent.

4.1.1 Duty Period

If the time of work is too extended, the human body tends to react negatively and the response is unpredictable. This is simply a disinclination of the brain to continue producing the same response over and over again to the same stimulus. This disinclination may result in a mistimed response or the intrusion of inappropriate responses.

Long periods of duty not only impair task performance but are also accompanied by increases in absences due to sickness and accidents (Grandjean, 1969). Furthermore, it is also demonstrated that striking the appropriate balance between daily hours and weekly hours is important if fatigue effects are to be avoided.

4.1.2 Rest Pause

Taking breaks before, during and after a period of duty is necessary for biological reasons. It is known that blood sugar levels decline to a low level about 3-4 hours after a meal resulting in a sensation of fatigue and impaired efficiency (Haggard et al. 1935). Perception and decision making is found to be temporarily affected after a midday meal (Bjerner et al. 1955).

Rest pauses are known to have essential restorative functions, but it can not be assumed that performance will inevitably be restored to its initial level when work resumes. The timing of breaks within each 24-h period, as well as within and around the duty period, seems important if human performance is to be maintained at the level demanded by certain tasks, especially those requiring alertness and continuous vigilance (Brown, 1994).

4.1.3 Sleep Breaks

To remedy and prevent longer-term fatigue, sleep breaks are a necessity and justifiable on the basis of both common sense and a long-published history of research on the subject of sleep. The longer the spell of duty, the more stressful the task, and the more hazardous the working conditions, the more restitutive sleep the individual will be obliged to take.

Froborg (1985) summarized evidence on the increases in micro sleeps that occur with increasing duty time and loss of sleep. These periods of few seconds of sleep result in an increased probability of human error. A Nap is important, but depends on what time of the day it is taken and its duration.

Sleepiness is a particularly important form of fatigue related to the level of brain stimulation and the structures that regulate it (Åkerstedt et al. 2000). In behavioral terms, there are four levels of sleep:

- Completely awake;
- Moderate sleepiness when the central nervous system maintains an adequate pattern but functions more slowly than normal (Angus et al. 1985);
- Severe sleepiness, where the individual is repeatedly overcome by fatigue, the interaction with environment becomes interrupted and performance becomes irregular. This characterizes such disorders as narcolepsy (Valley & Broughton, 1983), as well as totally healthy, but exhausted, individuals (Torsvall et al. 1987).
- Sleep, where there is no longer any interaction with the surrounding environment.

The level of fatigue or sleepiness is a function of the amount of activity (for example, the number of hours awake) in relation to the brain's physiological waking capacity.

4.1.4 Circadian Rhythm

Circadian rhythms in human arousal and performance appear to be of crucial importance for any assessment of fatigue effects on safety arising from an individual's working arrangements. The effect of circadian rhythms on human beings has been researched for more than 30 years. Practical implications on circadian rhythms from irregular and abnormal hours of working have been covered by the work of Rutenfranz et.al (1976), Folkard et al. (1985), Akerstedt (1988). The main conclusion from all previous studies is that there is not a single performance rhythm, but there are many. Different types of performance rhythms seem to adjust to irregular or abnormal working hours in different ways. The extent to which performance is impaired is a function of several interacting factors, including individual characteristics, domestic circumstances, and environmental conditions. The end result of these factors as Mitler et al. (1988) pointed out is that human medical and performance catastrophes are far more likely to occur between 1:00 a.m. and 8:00 a.m., with a secondary period of vulnerability between approximately 2:00 p.m. and 6:00 p.m.

The effect of circadian rhythms is important in analyzing fatigue related accidents. The European Transport Safety Council reported that most accidents occur between 2 A.M. and 5 A.M., with a secondary, lower peak between the afternoon hours of 3 P.M. to 4 P.M. The figures in the early morning hours are often ten or more times higher than daytime levels. Again, such data are consistent when international figures are considered. The survey of bus drivers conducted in Peru indicated that accidents and near accidents while driving occurred mainly between midnight and 6 A.M., and that having an accident or a near-accident was strongly associated with fatigue and with having the eyes intermittently closed while driving. (De Castro et al. 2004).

The 1996 Commercial Motor Vehicle/Driver Fatigue and Alertness Study performed in the United States by the Federal Highway Administration's Office of Motor Carrier

Safety is the largest and most comprehensive over-the-road study carried out on driver fatigue and alertness in North America. The study looked at the following factors: hours of driving during a work period; number of consecutive days of driving; time of day when driving took place, and schedule regularity. It reported that night driving was associated with the worst performance. It also noted that the time of day was a significant predictor of decreased driving performance, perhaps even more so than hours of driving or the cumulative number of trips made.

The Freight Transportation Association in the United Kingdom, which represents about half of the nation's fleet, also recognizes that time of day is a major factor in driver fatigue. In its 2002 publication, *Driver Fatigue: A Guide for Transport Managers*, the Freight Transportation Association points out those drivers are most vulnerable to sleepiness between 2 A.M. and 6 A.M, and 2 P.M. to 4 P.M.

4.2 Fatigue and Professional Drivers

Drivers of heavy-goods vehicles that regularly deliver freight over long distances may be at risk from fatigue effects because they are not free to determine their work schedules and because their job demands often involve irregular hours of work. Several different mechanisms could contribute to how fatigued an individual is, including loss of sleep, length of working hours, age, health status, general sleep quality, experience at work, motivation, home/family life and responsibilities, and commuting times. Truck drivers get fatigued through travel stress, and often fail to enjoy good quality sleep because they are working late to complete jobs. Konz (1998) supported the fact that one of the main reasons that people become fatigued is insufficient rest. This can result from working at the wrong time or working too many hours.

For truck drivers, the stressors could also include the pressure of their delivery or pick up schedule, road conditions, and different (inter-state) road rules and regulations. In a study conducted by Arnold et al. (1997), Australian truck drivers were questioned about how tired they were feeling and how many hours they had driven or were expected to drive. Over two-thirds of the drivers reported driving for over 14 hours in a 24-hour period, and just over half of them thought they had driven for over 14 hours in addition to performing other non-driving work. Around 12% of drivers reported having fewer than four hours of sleep on one or more working days. While some drivers thought that fatigue was a problem for them, the drivers considered that it was much more of a problem for other drivers, a finding that has also been reported in U.S. studies (Federal Motor Carrier Safety Administration, 1996). This perception may be particularly dangerous because it might signal that drivers are either unwilling or unable to assess their own fatigue levels accurately, and as a result, they might not take breaks when needed. When asked what variables they thought contributed to fatigue, 70% of managers of truck companies believed that long working hours were a major cause, and 40% of drivers agreed with this. Other reported causes of fatigue included lack of sleep, inexperience, and the non-driving work drivers also had to perform, such as loading the truck.

An experimental field study by Meijman (1997) utilized objective measures of fatigue with a sample of bus drivers and driving examiners in The Netherlands. The researchers noted that after seven hours of work and sleep loss, information processing broke down, a result that was interpreted as a serious sign of mental fatigue. Performance could no longer be sustained, even when extra effort was exerted on the part of the individual. A similar methodology was used by Williamson et al. (1996), who collected various data, both subjective and objective, on the fatigue of Australian truck drivers. These researchers found that fatigue increased across all trips taken (which averaged 12 hours). They considered that the pre-trip level of fatigue was important in determining fatigue at work.

The most comprehensive research undertaken into the effects of driver fatigue has been carried out in the United States. A series of studies by the National Transportation Safety Board (NTSB) has pointed to the significance of sleepiness as a factor in accidents involving heavy vehicles (NTSB, 1995). In a more recent report published by NTSB (1999) summarizing the U.S. Department of Transportation's investigations into fatigue in the 1990s, the extent of fatigue related fatal accidents was estimated to be around 30%. Fatigue is considered the most important road safety risk factor for large trucks.

4.3 The Effects of Long Hours on Levels of Fatigue

Studies link long working hours and fatigue by using objective and subjective measures of fatigue to determine the exact nature of their relationship. A recent study looking at fatigue and long hours was conducted by Park et al (2001). The researchers examined the relationship between working long hours and subjective fatigue complaints of a group of workers in South Korea. They were ultimately trying to determine whether subjective complaints of fatigue could be used as a screening tool for early detection of cumulative fatigue. The researchers had previously detected a relationship between long working hours and poor cardiovascular outcomes in earlier studies. Their hypothesis was that overtime work is associated with chronic fatigue and in turn, leads to decreased cardiovascular functioning. The researchers found that complaints of fatigue before going to work were lower for those men who worked shorter hours. Shorter hours were defined as fewer than 60 hours a week.

4.4 Fatigue and Accidents

Fatigue causes the loss of alertness in a driver, which is accompanied by poor judgment, slower reaction time, and decreased skill levels. Therefore, a driver's ability to concentrate and make critical decisions is reduced, and it takes longer to interpret and understand a traffic situation. Fatigue is a significant problem in the road transport sector in terms of the health and quality of life of drivers, as well as in the potential for accidents.

Data from a number of countries, including the United States, Israel, Germany, and Sweden, demonstrate that falling asleep at the wheel accounts for a considerable proportion of vehicle accidents on motorways, and the majority of these involve long-haul drivers. In New Zealand between 2002 and 2004, driver fatigue was identified as a contributing factor in 134 fatal crashes and 1,703 injury crashes (approximately 11% of fatal crashes and six percent of injury crashes each year) (Land Transport 2005). Australian estimates indicate that fatigue accounts for up to 30% of single-vehicle crashes in rural areas, official statistics in South Africa show similar trends, with fatigue contributing to 25 to 35% of all fatal accidents (Essenberg, 1999). Driver fatigue in the United States accounts for approximately 100,000 heavy vehicle accidents and 1,500 fatalities per year, as reported by the National Transportation Safety Board. Fatigue is a factor in an estimated 30 to 40% of trucking accidents and 15% of fatal crashes involving trucks. It is also estimated that the annual cost of fatigue-related trucking accidents in the United States is $5 billion. The problem is not unique to the United States, however. In the 2001 European Transport Safety Council report, "The Role of Driver Fatigue in Commercial Road Transport Crashes," driver fatigue is identified as a significant factor in approximately 20 % of commercial road transport crashes. The report also notes that more than 50 % of long-haul drivers have fallen asleep at the wheel.

4.5 Reducing Accidents Due to Fatigue

Pairing drivers as a team with sleeper cabin trucks can greatly reduce fatigue. In their study, Klauer et al. (2003) concluded that team drivers are better able to manage their fatigue and critical incident involvement than are single drivers. Possible explanations for these findings are that the team drivers are more likely to effectively trade-off driving duties with their partner prior to becoming extremely fatigued; whereas, single drivers tend to continue driving even when they show and feel advanced symptoms of fatigue. Klauer et al. (2003) noted that single drivers were exhibiting signs of extreme fatigue during all hours of the day, while team drivers only showed signs of fatigue during the nighttime and morning hours. This trend, along with generally lower numbers of incidents, is probably indicative of effectively trading-off driving duties.

4.6 Summary of Driver Fatigue

The results of the studies examined here show that fatigue is an important risk factor in driver health, as well as the safety of the general public. The effects of fatigue on driver performance have been documented in numerous studies in which subjects were required to perform driving tasks after long hours of wakefulness. Fatigue manifests itself in:

- Slower reaction times: Fatigue increases the time taken to react in an emergency;
- Reduced vigilance: Subjects perform worse on attention-based tasks when they are sleep-deprived. For example, a fatigued driver will be slower than; other road users. to notice oncoming hazards, such as road work or a railway crossing.
- Information processing: Fatigue reduces both the ability to process information and the accuracy of short-term memory. Thus, a fatigued driver may not remember the previous few minutes of driving and will be slower in evaluating oncoming hazards.

All the determinants of fatigue are important and greatly affect the truck driver, but it is observed that circadian rhythms of physiological activation have a profound effect on driver's relative accident risk. These rhythms have associate bimodal troughs in alertness: a major one in the early morning hours and a subsidiary one in the early afternoon.

CHAPTER 5

CONCLUSIONS AND SUGGESTIONS

The findings of the studies cited in this thesis, show clearly that truck drivers are at a continuous risk of developing health problems from the effect of long hours of driving. The average number of hours worked in the United States annually has increased over the past several decades and currently surpasses most countries in Western Europe and Japan (Caruso et al. 2004). The primary question being asked is whether there are more adverse health consequences as a result of longer hours of work. Though this thesis places particular emphasis on truck drivers, drivers of other kinds of heavy equipment, taxis, limousines, buses, lift trucks, tractors and other heavy farm machinery, and delivery trucks share the problems described here. Thus, it is safe to assume that the findings of the current study will also be relevant to those populations and the recommendations that will be offered will be equally helpful to all commercial and professional drivers.

The truck driver is more important than the goods being transported. Continuing study of the health hazards associated with the truck driving profession is important to reduce down time, but more importantly, to prevent permanent injuries, debilitating illnesses, workers' compensation claims, and road accidents.

NIOSH in its report of 2003-2006 has presented relevant statistics to show the rising cases of truck driver injuries and illnesses. Truck drivers consistently sustain more non-fatal occupational injuries and illnesses than the majority of the occupations. Recent evidence suggests that driver health, including sleepiness, fatigue, and inattention affects performance, as measured by the risk of being in a fatal crash (Bunn, 2005). From the literatures reviewed, there is a general conclusion that truck drivers are still exposed to risks caused by prolong driving, such as fatigue and whole body vibration. These risk factors have been implicated in most of the studies as the cause of the following common health problems of truck drivers: (a) Hypertension, cardiovascular disease and stroke, (b) Musculoskeletal disorders, (c) Higher risk of lung cancer, (d) Obesity, and (f) Sleep disorders and psychological distress. It is expected that elimination of the risk factors will greatly safeguard truck drivers and improve the quality of the services they render.

Based on the articles reviewed in this thesis, and the physiological mechanisms behind the various health related issues associated with truck drivers, the following set of suggestions have been developed to improve the general occupational condition of long haul truck drivers. The suggestion set should help policy makers, schedulers and truck drivers to reduce the stress levels of the occupation and improve the health status of truck drivers. The suggestions are as following:

1. Drivers need to avoid prolonged exposure to driving, take regular rest breaks, avoid overtime work, make sure to regularly have days off, take vacations, and whenever possible be away from traffic and motor vehicles.

2. Truck stops should be built on all major long haul roads to encourage drivers to stop and rest. Major truck stops should have exercise equipment for use by drivers, and should have a nurse's office to monitor some basic health conditions of the on-duty road driver.

3. Develop a more stringent support of the regulated driving time to infuse a sense of safety in the thinking of truck driver employers and end users of freighted goods. This will reduce stress and pressure imposed on drivers due to delivery schedules.

4. Truck drivers should strive to maintain a stable family life and social support network of friends and acquaintances, would help mitigate the psychosocial stressors of the

job. Drivers should help their psychological condition by sharing work experiences with supportive colleagues, friends, and family.

5. Air monitoring devices should be considered for placement in the cabin of trucks to occasionally monitor air quality.

6. Drivers should be encouraged to stop smoking. Drivers should have regular medical check-ups; especially checking blood pressure regularly, if at all possible during work. In addition, recommendations include regularly performing an ECG, blood cholesterol (total and LDL fraction), triglyceride and glucose levels, and having a chest x-ray taken periodically.

7. Safety professionals should start planning how to help drivers avoid the use of stimulants, including excessive coffee intake. Avoid late night driving, if at all possible.

8. Review cabin design to allow for more flexibility and room for air exchange.

APPENDIX A

NONFATAL OCCUPATIONAL INJURIES AND ILLNESSES FOR THE GENERAL LONG DISTANCE FREIGHT TRUCKING INDUSTRY AND ALL U.S PRIVATE INDUSTRY, 2003 – 2006

Incidence rates (1) of nonfatal occupational injuries and illnesses involving days away from work (2) by selected worker and case characteristics and industry, All U.S., private industry, 2003 – 2006					
Characteristic	Private industry (3) (4) (5)	General Freight Trucking, Long-Distance			
	2006	2003	2004	2005	2006
Total:	127.8	351.6	301.2	315.5	279.8
Number of days away from work:					
Cases involving 1 day	18.3	35.6	22	35.3	26.2
Cases involving 2 days	14.8	28.6	24.2	25.6	21
Cases involving 3-5 days	23.7	51.1	44.4	54.7	48.3
Cases involving 6-10 days	16.5	43.3	41.2	41.7	31.2
Cases involving 11-20 days	14.7	39.1	41.1	36.9	30.6
Cases involving 21-30 days	8.7	25.4	19.1	24.3	23.2
Cases involving 31 or more days	31.1	128.3	109.3	97.1	99.4
Nature of injury, illness:					
Sprains, strains	51.1	170.1	149.1	159.9	131.8
Fractures	10.2	37.3	30.6	21.3	30.2
Cuts, lacerations, punctures	12.4	14	10.3	12.9	10.8
Bruises, contusions	10.9	37.5	33.6	29.5	33.8
Heat burns	1.9	0.8	-	-	0.9
Chemical burns	0.8	4	1.1	1.4	1.7
Amputations	0.9	2	-	0.4	1.2
Carpal tunnel syndrome	1.4	2.4	1.5	1.7	1
Tendonitis	0.5	-	1.2	0.7	0.4
Multiple injuries	5	13.8	16.7	14	14.3
With fractures	1.1	3.1	3.1	4.2	2.5
With sprains	1.9	6.4	7.6	5.3	4.9
Soreness, Pain	11.3	24.6	18.2	26.3	15.2

Back pain	3.8	8.7	5.9	12.1	6
All other	21.4	44.5	38	47.1	38.7
Part of body affected:					
Head	8.9	15.8	18.6	19.1	15.9
Eye	3.9	1.9	7.1	5	4.3
Neck	1.9	7.5	7.8	5.7	8.4
Trunk	43.4	134.9	117.3	132.5	104
Back	27.1	78.2	64.4	80.3	55
Shoulder	8.2	30.4	28.5	28.2	26.7
Upper extremities	29.6	66.8	53.7	40.1	48.4
Finger	11.5	13.5	12.1	10.4	8.3
Hand, except finger	5.3	15.6	7	5.1	7
Wrist	5.3	14.3	10.4	7.4	10.9
Lower extremities	28.3	80.5	63.8	78.4	65.1
Knee	10.3	29.9	21.7	28.7	23.3
Foot, toe	6.2	13.4	12.3	13.5	12
Body systems	2	1.7	2.6	2.2	2.3
Multiple	12.5	42.2	36.4	34.2	33.4
All other	1.2	2.4	1	3.3	2.4
Source of injury, illness:					
Chemicals, chemical products	2.1	5.5	3.2	4.1	3.7
Containers	15.9	45.1	37.1	50.2	33.5
Furniture, fixtures	4.9	5.7	6.4	3.4	3.7
Machinery	8.4	10	5.5	6.6	4.5
Parts and materials	13.5	43.9	37.2	35.9	37.9
Worker motion or position	17.6	47.3	35.3	38	33.6
Floor, ground surfaces	23.2	80.4	57.4	68.5	62.9
Hand tools	6.1	6.3	7.2	5.3	4
Vehicles	10.9	83.9	89.5	82	75.9
Health care patient	5.7	-	-	-	-
All other	19.5	23.5	22.5	21.4	20.2
Event or exposure:					
Contact with object, equipment	36.2	77.3	65	66.3	56.5
Struck by object	17.8	42.2	33.4	34.8	29.6
Struck against object	9.3	20.6	18.5	14.2	15.5
Caught in object, equipment, material	6.4	10.3	9.3	11.8	6.9
Fall to lower level	8	35.2	30.4	36	36.2
Fall on same level	16.4	49.4	29	34.5	31.5
Slips, trips	3.8	13.5	9.2	10.3	8.3
Overexertion	30.8	77.3	75	86	66.9
Overexertion in lifting	16.3	27.9	27.3	33.7	21.5

Repetitive motion	4.1	8.5	3.5	3.7	3.5
Exposed to harmful substance	6.1	6.8	4.8	5	6
Transportation accidents	6.1	45.7	51.6	37.2	37.9
Fires, explosions	0.2	1.1	-	0.4	0.3
Assault, violent act	2.4	1.1	2.2	1.1	2.8
by person	1.7	-	1.5	0.4	0.9
by other	0.7	-	-	0.7	1.9
All other	13.6	35.6	29.9	34.8	29.9

Footnotes

(1) Incidence rates represent the number of injuries and illnesses per 10,000 full-time workers and were calculated as: (N / EH) X 20,000,000 where,
N = number of injuries and illnesses,
EH = total hours worked by all employees during the calendar year,
20,000,000 = base for 10,000 full-time equivalent workers (working 40 hours per week, 50 weeks per year).

(2) Days away from work cases include those that result in days away from work with or without job transfer or restriction.

(3) Excludes farms with fewer than 11 employees.

(4) Data for mining (Sector 21 in the North American Industry Classification System -- United States, 2002) include establishments not governed by the Mine Safety and Health Administration (MSHA) rules and reporting, such as those in oil and gas extraction and related support activities. Data for mining operators in coal, metal, and nonmetal mining are provided to BLS by the Mine Safety and Health Administration, U.S. Department of Labor. Independent mining contractors are excluded from the coal, metal, and nonmetal mining industries. These data do not reflect the changes Occupational Safety and Health Administration made to its recordkeeping requirements effective January 1, 2002; therefore estimates for these industries are not comparable with estimates for other industries.

(5) Data for employers in railroad transportation are provided to BLS by the Federal Railroad Administration, U.S. Department of Transportation. These data do not reflect the changes Occupational Safety and Health Administration made to its recordkeeping requirements effective January 1, 2002; therefore estimates for these industries are not comparable with estimates for other industries.

NOTE: Because of rounding and data exclusion of no classifiable responses, data may not sum to the totals. Dashes indicate data that do not meet publication guidelines. The scientifically selected probability sample used was one of many possible samples, each of which could have produced different estimates.

SOURCE: Bureau of Labor Statistics, U.S. Department of Labor, Nov 27, 2007
From: http://data.bls.gov/GQT/servlet/InitialPage with the following qualifiers
(a) Case and Demographic Incidence Rates
(b) year 2006
(c) All US and beginning year 2003
(d) Industry and Numeric
(e) 48412X General Freight Trucking, Long-distance and Private Industry

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