Work Related Musculoskeletal Discomfort among Iranian Heavy Truck Drivers

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ABSTRACT

Musculoskeletal Disorders (MSDs) are the common health problems among individuals in different occupations. Heavy truck drivers are exposed to various psychological, psychosocial and physiological factors such as Whole Body Vibration (WBV), awkward positioning, bad eating habits and etc. which some of them cause the prevalence of musculoskeletal discomfort in different body regions. In Iran, the prevalence of musculoskeletal discomfort among the heavy truck drivers is a mutual concern. Thus, investigation related to association of different factors with prevalence of musculoskeletal discomforts is necessary.

Cross sectional study method is applied in order to assess association of factors with the occurrence of musculoskeletal discomforts. 384 Iranian heavy truck drivers are interviewed by an updated Nordic Musculoskeletal Questionnaire (NMQ). Furthermore, hypothesis testing is used to assess the associations of different factors and musculoskeletal discomfort reported by participants. Logistic regression method is used to investigate the different correlations among questions of the survey and different body sections that Interviewees experience trouble as well. Moreover, Rapid Entire Body Assessment (REBA) technique is applied for various positions of drivers whom used in order to fulfill different job tasks.

Results demonstrate that 57% of the drivers are suffering from discomfort in their lower back region. Additionally, neck, left shoulder, right shoulder, knees and upper back, are among the high prevalence region that musculoskeletal discomfort has been reported. Hours of exposure to vibration were associated with discomfort of neck (p-value=0.00) and shoulders area (p-value=0.00); though, such a relation was not found for the discomfort of lower back (p-value=0.30). In addition 24 mathematical equations have been illustrated with significant predictors' questions and their correlations with the prevalence musculoskeletal discomfort of different body regions of truck drivers. REBA method improved three different positions of the truck drivers; however, seating position behind the steering wheel is remains at high risk position category (REBA score=10).

Keywords: Musculoskeletal disorders, WRMSD, REBA, Logistic regression, Nordic Musculoskeletal Questionnaire

ÖZ

Kas-iskelet sistemi hastalıkları (KİSH) farklı mesleklerdeki bireyler arasındaki ortak sağlık sorunları arasında bulunmaktadır. Ağır kamyon şoförleri, Tüm Vücut Titreşim (WBV), garip konumlandırma, kötü beslenme alışkanlıkları vb gibi sebepler ile vücutlarının farklı bölgelerinde kas iskelet rahatsızlığına neden olabilicek çeşitli psikolojik, psikososyal ve fizyolojik faktörlere maruz kalmaktadırlar. İran'da, ağır kamyon sürücüleri arasında kas-iskelet rahatsızlıkarının yaygınlığı endişe edilen bir hususu oluşturmaktadır. Böylece, kas-iskelet rahatsızlıkları yaygınlığı ile farklı faktörlerin arasındaki ilişkinin araştırılması gerekmiştir.

Kesitsel çalışma yöntemi kas-iskelet rahatsızlıkları ortaya çıkması ile faktörlerin ilişkisinin değerlendirilmesi amacıyla uygulanır. 384 İranlı ağır kamyon sürücüsüne güncelleştirilmiş Nordik Kas-iskelet Anketi (NMQ) uygulanmıştır. Ayrıca, hipotez testi kullanarak farklı faktörler ve katılımcılar tarafından bildirilen kas-iskelet rahatsızlıkları arasındaki ilişki değerlendirilmiştir. Lojistik regresyon yöntemi anketin soruları ve farklı vücut bölümleri arasındaki farklı ilişkiyi araştırmak için kullanılmıştır. Ayrıca, Hızlı Bütün Vücut Değerlendirmesi (REBA) tekniği kullanılarak şoförlerin çeşitli pozisyonlarda farklı iş görevleri incelenmiştir.

Sonuçlar sürücülerin %57'sinin alt sırt bölgesindeki rahatsızlıktan muzdarip olduğunu göstermektedir. Ayrıca; boyun, sol omuz, sağ omuz, diz ve üst sırt, kas-iskelet rahatsızlıklarında rapor edilen yüksek prevalans bölge arasında yer aldığı ortaya çıkmıştır. Titreşime maruz kalmanın saat boyun rahatsızlık (p-değeri = 0.00) ve omuz alanı (p-değeri = 0.00) ilişkisi bulunmuş olsa da, böyle bir ilişki alt sırt rahatsızlık (p-değeri = 0.30) için bulunmamaktadır. Ek olarak 24 matematik denklemiyle kamyon sürücülerinin değişik vücut bölgelerinde yaygın olarak kas-iskelet rahatsızlığı ile anlamlı yordayıcı soruları ve korelasyonları ile gösterilmiştir. REBA yöntemi kamyon sürücüleri üç farklı pozisyonlarında geliştirilmiştir. Ancak direksiyon simidinin arkasında oturma pozisyonu yüksek riskli pozisyon kategorisinde kalmıştır (REBA puanı = 10).

Anahtar kelimeler: Mesleki kas-iskelet bozuklukları, REBA, Lojistik regresyon, Nordik Kas-iskelet Anketi

To My Dear Family

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LIST OF ABBREVIATIONS

ANOVA	Analysis of Variances
BMI	Body Mass Index
CMDQ	Cornell Musculoskeletal Discomfort Questionnaire
DMDQ	Dutch Musculoskeletal Discomfort Questionnaire
LBP	Lower Back Pain
MSD	Musculoskeletal Disorder
NIOSH	National Institution of Safety and Health
NMQ	Nordic Musculoskeletal Questionnaire
OWAS	Ovako Working posture Analysis System
REBA	Rapid Entire Body Assessment
RULA	Rapid Upper Limb Assessment
WBV	Whole Body Vibration
WERA	Work Ergonomic Risk Assessment
WRMSD	Work-Related Musculoskeletal Disorders

Chapter 1

INTRODUCTION

1.1 Background Study

Musculoskeletal disorders (MSDs) are “injuries or disorders of the muscles, nerves, tendons, joints, cartilage, an disorders of the nerves, tendons, muscles and supporting structures of the upper and lower limbs, neck, and lower back that are caused, precipitated or exacerbated by sudden exertion or prolonged exposure to physical factors such as repetition, force, vibration, or awkward posture” ("NIOSH," 2015). MSD is one of the most common health problems among individuals in different occupations (Millennium, 2003). In many developed countries, disorder of musculoskeletal is the largest illness reported by different occupational individuals (Punnett and Wegman, 2004). MSDs in different body regions have association with different job tasks. For instant, those who work in ware houses are more likely to suffering from the Low Back Pain (LBP). LBP are commonly related with lifting heavy weights frequently and continuous exposure to Whole Body Vibration (WBV) as well (Waters *et al.*, 1993).

The correlation between WBV and occupational MSDs has been observed among drivers (Seidel and Heide, 1986). Other than WBV, Palmer *et al.* (2001) have concluded that vibrations which are transmitted from the hands are associated with neck and shoulders disorders. Nonetheless, primary work-related injuries are the logical predictor for MSDs because of the relation between chronic events and severity of the pain (Alexopoulos *et al.*, 2006).

According to Rahman 2013, occupational driving is mostly associated with neck and LBP and truck drivers are often exposed to this trouble. High musculoskeletal discomforts are related to high driving millage (Gyi and Porter, 1998; Porter and Gyi, 2002). In addition, awkward positioning among truck drivers are connected with neck and trunk pain (Massaccesi *et al.*, 2003).

“Work-Related Musculoskeletal Disorders (WRMSDs) are a group of painful disorders of muscles, tendons, and nerves” (OSHA, 2014). Since occupational driving contains continual repetition of movements, fixed or constrained body positions and force concentrated on small parts of the body, MSDs related to this job are categorized as WRMSDs (OSHA, 2014). Occupational driving MSD is one of the concerns of public health in developing and developed countries where millions of truck drivers suffering from spinal, upper and lower back severe pains. These countries are trying to understand related problems and factors in the past decades (Rahman, 2013).

1.2 Significance of Study

Among developing countries there are not enough researches, conducted about work-related MSD and particularly in Middle East region. Especially in Iran, there are not adequate resources on WRMSD; which states that there is a quite large gap in the literature to be filled. Cross sectional study is an appropriate tool for these scenarios; however, they are only suitable for investigating the different factors on musculoskeletal troubles. This study is conducted to gather relevant information about the work-related musculoskeletal discomfort and find the relation of several demographic and occupational factors with it. Eventually, this research creates an opportunity for more advanced investigations about the effect of factors which are associated with MSDs and find appropriate solutions for different ergonomic implementation tools.

1.3 Aims and Objectives

An updated version of Nordic Musculoskeletal Questionnaire (NMQ) is retrieved from the study of Robb and Mansfield (2007) and used for interviewing with the truck drivers of Iran. This research aims to investigate the association of musculoskeletal discomfort of different body parts with psychosocial and physiological factors. The case study of this thesis is the occupational truck drivers whom located in Iran.

1.4 Hypotheses

11 hypotheses are claimed based on the previous researches which are mentioned in the literature. Additionally, 3 more hypotheses are added to the previous ones in order to provide a better coverage on the questionnaire results. The 14 hypotheses are as follows:

H_1: there is an association between smoking status and discomfort of low back area which has been reported during the last 12 months among truck drivers.

H_2: there is an association between weekly hours of exposure to vibration and discomfort of low back area which has been reported during the last 12 months among truck drivers.

H_3: there is an association between weekly hours of exposure to vibration and discomfort of neck area which has been reported during the last 12 months among drivers.

H_4: there is an association between weekly hours of driving and discomfort of shoulders area which has been reported during the last 12 months among drivers.

H_5: Most of the drivers experience Low back discomfort during the last 12 months.

H_6: there is an association between night shift and Body Mass Index (BMI).

H_7: there is an association between BMI and discomfort of low back area which has been reported during the last 12 months among drivers.

H_8: there is an association between age of the drivers and number of musculoskeletal discomfort which has been reported by each driver during the last 12 months.

H_9: There is a significant association between the intensity of the low back discomfort during the worst episode and hours that truck drivers are being prevented from work.

H_{10}: there is a significant relation between drivers who experience accident and the number of body part they have experienced musculoskeletal discomfort during last 12 months.

H_{11}: weekly hours of exposure to vibration is significantly associated with the number of body part which truck drivers have experienced musculoskeletal discomfort during last 12 months.

H_{12}: There is a significant association between seat comfort and discomfort of neck area which has been reported during the last 12 months among drivers.

H_{13}: There is a significant association between seat comfort and discomfort of shoulders area which has been reported during the last 12 months among drivers.

H_{14}: There is a significant association between seats with easy to adjusted lumber support and discomfort of low back area which has been reported during the last 12 months among truck drivers.

1.5 Research Methodology

The method for each hypothesis is chosen based on the dependent and independent variables of it. Chi-square test of independence, proportion binomial test and Analysis of Variances (one way ANOVA) are the test methods implemented on 14 hypotheses. In addition to 14 hypotheses, Pearson correlation, binary and multinomial logistic regressions are utilized in order to fully investigate different relations between questions of the questionnaire. Eventually, three positions are selected and assessed by Rapid Entire Body Assessment (REBA) method. These three postures were selected based on most awkward, heaviest weight lifting and most constant positions that drivers use to do different job tasks. And then after, these three postures are optimized in order to reduce the REBA score.

1.6 Structure of the Thesis

This study is organized in six chapters. Chapter 1 contains Background study, Significant of study, Aims and objectives, Hypotheses, Research methodology and structure of the thesis. Chapter 2 discuss about the studies which are already applied related to the field of this research. Chapter 3 explains the methods which have been used in this study. Chapter 4 includes the statistical results of the methods which are used in this study; and moreover, illustrates solutions with regards to different postures of the drivers. Chapter 5 demonstrates the comparison of the results with previous research. Additionally, the limitations of the research as well as suggestions for future studies are mentioned there. Finally in chapter 6, the point of view achieved by this research is explained.

Chapter 2

LITERATURE REVIEW

2.1 Physiological Factors and their Association with MSD

MSDs contain variety of medical conditions, which can cause some effect on bones, blood vessels, joints, tissue and even nerve cells (Punnett and Wegman, 2004). Some of the researches indicate that MSDs and LBP can be the result of a mixture of physical, mechanical and psychosocial factors (Bener and Galadari, 1998). In minor cases MSDs can damage soft tissues, ligaments, bones and tendons but in major cases this symptoms could result long term diseases like spinal degeneration, sciatica and also tumors in rare episodes (Bovenzi and Hulshof, 1998). Wikström *et al.* (1994) have found that LBP has effect on digestive, reproductive, vestibular, visual acuity system, abdominal pain, prostatitis and hemorrhoid as well. Evidence of MSDs can be found as result of discomfort following chores, intense pain, adjust to an awkward positioning or extreme physical action to which person is uninformed resulting sprain, strain or other biomechanical conditions (Smedley *et al.*, 2013).

Sadeghi *et al.* (2012) studied the association between MSDs and individual specifications such as weight and height has been studied. Leboeuf-Yde (2000) investigated the association of body weight with LBP and they found a statistically significant association between body weight and LBP. Other studies in the literature also show a relation between obesity and higher prevalence of MSDs (Brage and Bjerkedal, 1996; Han *et al.*, 1997; Heir and Eide, 1996; Leino-Arjas *et al.*, 1998;

Linton, 1990; Raanaas and Anderson, 2008; Skov *et al.*, 1996). Usually in other occupations the BMI is more likely lower than occupational drivers. A significantly higher BMI was reported by Hedberg *et al.* (1993) among truck drivers than other occupations. Raanaas and Anderson (2008) studied MSDs among Norwegian Taxi driver; the mean BMI with the sample size of 823 individuals was equal to 26.8 which 59.5 percentages has experienced LBP. They claim that drivers, who had BMI range between 20 to 28.99, had 57.5 percentage prevalence of MSDs. Above this range 63.6 percent of prevalence MSDs has been collected.

Researches show also the association of age and MSDs (Kilbom *et al.*, 1996). By increasing of age up to 55-59 the risk for most of the musculoskeletal disorder would raise (Kilbom *et al.*, 1996). As a result, the elder group of drivers is reducing due to their heavy physical job. Relatively, age factor in WRMSD were investigated by Gangopadhyay *et al.* (2012) on bus conductors. Their findings showed that the age and experience are critical factors related to MSDs. In their study, Okunribido *et al.* (2006) illustrated that younger groups or those with fewer years of experience reported less MSDs than those who were experienced and older.

Many researches have accomplished this view which argue a high prevalence of extreme and lifelong pain associated with lower back and lumbar part of driver’s body (Bovenzi and Zadini, 1992). Chen *et al.* (2005) demonstrated that, 51 percent of Taiwanese drivers reported discomfort in low back area. Johansson *et al.* (2012) found an increasing blood pressure rate among heavy truck drivers in contrast to the amount of work hours and also against WRMSD. Moreover, Robb and Mansfield (2007) studied the prevalence of LBP on truck drivers.

One of the biggest issues about WRMSD is that the individuals adjust their posture in order to temporarily avoid the intense pain of their body and negatively this posture would damage other parts of their body. Therefore, interventions in work places are important even for a short time due to manage their condition. Although it cannot be apply for drivers unless it is based on medical engagement. Especially the ones that medical sessions could not be successful after four weeks (Smedley *et al.*, 2013).

2.2 Psychosocial Factors and their Association with MSD

Besides all the physiological factors, other risk factors such as mileage of driving, working hours, awkward posture , WBV originating from the vehicle and even individual medical condition exist that have been considered in different studies (Massaccesi *et al.*, 2003; Robb and Mansfield, 2007; Sakakibara *et al.*, 2006; Sang *et al.*, 2010). Variety of symptoms in their nature and absence of a single causative factor makes them challengeable to diagnose by clinical professionals. Smedley *et al.* (2013) claimed that, only less than ten percent of the musculoskeletal disorders can be identified of a certain cause or can be related to a primary event.

Many studies have shown the consistency of the association of LBP and WRMSD with smoking. But it is too far from being the only factor (Ernst 1993; Kilbom *et al.* 1996). Many other researchers have argued about the smoking habits and its effect on accelerating degeneration at lumbar spine due to reduction of nicotine in blood flow. Previous studies (Bongers *et al.* 1990; Boshuizen *et al.* 1990; Bovenzi and Betta 1994; Sang *et al.* 2010) provided that there is strong association between LBP and prolong sitting posture, heavy lifting and smoking. The other danger is the exposure to chemical and biological hazards like environmental pollutants (Burgaz *et al.*, 2002).

In a study for sleeping habits of truck drivers, it has been concluded that obesity has an association with short duration sleeps or napping because of the uncertainty of their work shifts (Moreno *et al.*, 2006). Additionally Jack *et al.* (1998) and Moreno *et al.* (2006) have demonstrated that having a poor diet and sedentary activities are the other reasons for the higher BMI. Sleeping in vehicles can cause sciatica, whiplash neck injuries and spinal degeneration. Also it can increase the risk of rheumatism and osteoarthritis (Bovenzi and Zadini, 1992; Heliövaara, 1987; Raanaas and Anderson, 2008).

There is a complex phenomenon to the response of human body to vibration. Many researches have been applied for analyzing the effect of vibration on the human body and they demonstrated the diversity of it (Damkot *et al.*, 1984; Frymoyer *et al.*, 1983; Hulshof and van Zanten, 1987; Kjellberg *et al.*, 1994; Sandover, 1988; Seidel and Heide, 1986). Perception, health and comfort are the three categories of human response to WBV. WBV can affect the musculoskeletal health by biomechanical and physiological responses from exposure (Wikström, 1994). Vibration of a vehicle transfer to drivers body as a force by the vehicle seat and shakes the whole body. It is also named as ‘seated WBV (Rehn, 2004). WBV can also transfer to the body in standing and lying posture but, it is not the case in this particular study. The association between exposure to WBV and LBP has been concluded in several studies (Bernard and Putz-Anderson, 1997; Bovenzi and Hulshof, 1998; Lings and Leboeuf-Yde, 2000; Mirzaei and Mohammadi, 2010). Yet there has not found any relation between the LBP and the dose of the exposure. Consequently the exposure to

WBV is the general assessment for LBP in different occupations. Previous researches did not conclude an association between WBV and discomfort in neck and shoulder symptoms (Bernard and Putz-Anderson, 1997; Bovenzi and Hulshof, 1998; Wikström *et al.*, 1994). On the other hand vibration has some benefits as well which has been utilized and studied by different groups of therapists (Keller *et al.*, 2000). Most importantly these benefits have been used for increasing the muscular strength in lower limbs or lower back (Bosco *et al.*, 1999; Bosco *et al.*, 1998; Issurin *et al.*, 1994; Issurin and Tenenbaum, 1999). By these aspects, not all types of vibration can be expressed as a harmful index. However, it is critical to determine the components of detrimental vibration and it can be established by comparison of the outcome data, accurate description and variables of the vibration such as direction, magnitude, frequency and duration of it. Lots of studies show a clear association of MSDs and LBP with a number of variable factors such as WBV, which is the main cause for spine degeneration and herniated disc as well as lumber and ligament discomfort (Bovenzi and Zadini, 1992; Chen *et al.*, 2005; Damkot *et al.*, 1984; Kelsey and Hardy, 1975; Krause *et al.*, 2001; Sadri, 2002; Tiemessen *et al.*, 2008).

In most epidemiological researches, WBV in vertical direction is more likely to be the cause of WRMSD than the horizontal. Another study by Magnusson *et al.* (1996) reported a more dramatic result as they claimed that 81% of bus drivers had LBP because of the WBV and heavy lifting.

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Sadri, 2002; Tiemessen *et al.*, 2008). Activities like lifting weights show a higher prevalence of Work related MSDs and specially on low back region than those drivers who do not handle these items (Poitras *et al.*, 2008).

2.3 Psychological Factors and their Association with MSD

Leino and Magni (1993) studied the association of depressive symptoms would cause the future musculoskeletal disorders; however, they showed that having a musculoskeletal disorder is not a predictor for future depression. Moreover, Magni *et al.* (1994) concluded that, the depression can be strongly be effected by chronic musculoskeletal pain. They also found other factors such as low education, being unemployed, living in areas which the population exceed 250000 people and even gender, are powerful predictors for depression.

Patten *et al.* (2006) found a strong association between arthritis or rheumatism and prevalence of mood, anxiety and substance use disorders.

Related to work-related prevalence of psychological factors, study of da Silva-Júnior *et al.* (2009) demonstrated 13.6 % prevalence of depression among truck drivers. They also found that being older than 45 years among drivers, can increase the risk of depression. Followed by age factor low educational status, wage-earning, self-employment and use of stimulants are strong predictors of depression. A study in Hong Kong by Wong *et al.* (2007) showed the prevalence of psychological factors among cross board and long distance truck drivers. The findings demonstrate 14.5% prevalence of depression, 25.9% anxiousness and 24.1% of sexual dysfunction. These prevalences were strongly associated with smoking and drinking habits. In this study, those who reported they have admitted risky sexual experiences, where more likely to be in the risk of depression.

2.4 Surveys Used for Musculoskeletal Discomfort Assessment

In order to select the applicable survey related to this study, the following sub-chapters discussed the reliability, validity, properties and objective of different surveys from the literature.

2.4.1 The National Institute for Occupational Safety and Health (NIOSH) Symptoms Survey Versus NMQ

The objective of NMQ is to be a simple standardize questionnaire which can be use like a screening method to evaluate MSD in ergonomic fields and epidemiologic studies. In the same way, NIOSH symptoms survey has a similar body description; however, for determining the severity of the discomfort, series of questionnaire has been added to the method which turns it to a qualify survey by using duration, frequency and intensity of the discomfort. The examination of these two surveys for reliability and validity has been done by Baron *et al.* (1996). This study discussed the NIOSH symptoms survey in comparison to NMQ. They assessed the reliability and validity of the mentioned surveys by test-retest methods. Consequently, both methods were accepted in case of reliability and validity. Appendix B illustrate a sample form of NIOSH symptoms survey (Cohen, 1997).

2.4.2 Dutch Musculoskeletal Discomfort Questionnaire (DMDQ)

This is a very powerful survey to investigate the relation of musculoskeletal discomfort with physical, psychosocial and psychological factors. Beginning with the general question about the participant, this survey contains two pages of health related, one page related to leisure-time and six pages of work-related factors which can effect or be affected by MSDs. After evaluating the factors associated with MSD, two special parts for low-back and neck and shoulder are demonstrated by this survey. Finally, in tow last pages are assigned for the personal opinion of individuals (Ergonomics, 2001).

Related to this questionnaire, Hildebrandt *et al.* (2001) focused on the description and basic qualities of DMDQ. They applied this method on 1575 workers in different studies. This survey contains 63 questions about musculoskeletal workload and their association with hazardous working conditions. These psychosocial factors can be categorize in to seven subcategories (Dynamic and static loads, climate factors, force, vibration, repetitive loads and ergonomic environmental factors) (Hildebrandt *et al.*, 2001). According to their data bases, homogeneity of these factors is acceptable. The validity of this survey is faire compared to psychosocial working condition. Subsequently, Hildebrandt *et al.* (2001) have concluded that, this questionnaire can be applied as a quick and simple inventory for work-related health services in order to select the group of workers which more ergonomic analyses are required. Appendix C shows the sample of DMDQ (Ergonomics, 2001).

2.4.3 Cornell Musculoskeletal Discomfort Questionnaire (CMDQ)

The same as other this survey is to investigate the prevalence of musculoskeletal discomfort. It is a simple survey which includes male and female body respectively. It focuses on the frequency, severity of the discomfort and whether it is preventing the participants in their occupation or not. All three factors are including a scale for makes the outcome data to be qualitative (Erdinc *et al.*, 2011; Jansen *et al.*, 2012).

This survey also is very applicable in cases where the case study participants are not native English speakers; because, it has been translated to different languages and related to the translation reliability and validity of the translated version has been considered (Afifehzadeh *et al.*, 2011; Erdinc *et al.*, 2011; Kreuzfeld *et al.*).

Separated from the reliability and validity of the translated versions, Bilberg *et al.* (2014) have test the reliability of this questionnaire in English language using test-retest method. They concluded that, with Cronbach's alpha of 0.94 for all the questions, there is a high internal consistency and therefore it is reliable.

In appendix D a sample form of CMDQ for male and female human anatomy has been demonstrated (Erdinc *et al.*, 2011; Jansen *et al.*, 2012).

2.4.4 Body Part Discomfort Map

Last but not least, body discomfort map is a survey to evaluate the musculoskeletal discomfort in the situation when the driver is sitting in the car seat. This method is mostly about the work-station of the drivers. Subsequently, it is a simple survey to evaluate the prevalence of musculoskeletal discomfort among drivers (Ergonomics). Appendix E shows a sample sheet of the mentioned survey (Ergonomics).

2.5 Posture Analyzing

Several methods are illustrated in order to analyze different body positions in different work stations. Among these surveys, Rapid Upper Limb Assessment (RULA), REBA and Work Ergonomic Risk Assessment (WERA) are described in the following sections.

2.5.1 RULA

This method is mostly focuses on the upper body positions in different tasks. It is a single page work-sheet which analyzes the most uncomfortable, the most constant or the highest force of workload positions for the individuals. It can be selected whether by the participant description of the positions or by the evaluator after interviewing and observation of different postures. This method divides the human body into two sections (left and right side) covering arm, wrists (section A), Neck, Trunk an legs (section B). Section B investigates, whether neck, legs and trunk influence the posture of arms and wrists or not. Subsequently, using three tables of the work sheet, a score can be specified for each position and this score illustrates the importance of implementing changes to the position. This final score started from 1 and as it increases, the risk and the importance of applying change to the position increase as well (Middlesworth, 1993). Appendix F shows a sample worksheet of RULA.

2.5.2 REBA

Analyzing the posture of activities has lots of benefits in order to avoid risks of MSDs (Hignett and McAtamney, 2000). Mostly postural analysis have two paradoxical indexes named as sensitivity and qualities of generality (Fransson-Hall *et al.*, 1995). For example, Ovako Working posture Analysis System (OWAS) which has been studied by Karhu *et al.* (1977), reveals a wide range of use however, the outcomes are detailed and small (Hignett, 1994). In other way NIOSH technique needs specific information about detailed parameters of the posture which the outcome would be sensitive, concerning the identified indices. However, it has limited application for health care respecting animate load handling (Waters *et al.*, 1993). These requirements developed the REBA as a postural analysis tool (Hignett and McAtamney, 2000; McAtamney and Hignett, 1995).

The same as RULA, this method has the same path to result a final score for investigating that how important the implication is for each posture; however, this method analyzes the entire bodies for the final score (Stanton *et al.*, 2004). Appendix F shows a sample of REBA worksheet (Middlesworth, 2000).

2.5.3 WERA

It is a simple method to investigate risk factors in a work place. These risk factors are posture, forceful, repetition, contact stress, vibration and task duration. The survey focus on five body parts (leg, back, neck, shoulders and wrists). Scoring system and related actions are prepared for this method (Ergonomics). Reliability and validity of this survey has been tested and accepted (Rahman *et al.*, 2012; Rahman *et al.*, 2011). Appendix F is a sample worksheet of WERA (Ergonomics).

Chapter 3

METHODOLOGY

3.1 Questionnaire

In order to determine prevalence of the musculoskeletal discomfort among heavy truck drivers, this study is based on designing similar questionnaire to Robb and Mansfield (2007). They used an updated version of the standard NMQ (Dickinson *et al.*, 1992; Kuorinka *et al.*, 1987). Also, in order to determine vibration exposure impact on musculoskeletal discomfort, their study was evaluated by questionnaire similar to those from a larger medical research council study (Palmer *et al.*, 1999). Appendix A shows a sample of this (Robb and Mansfield, 2007).

The first part of the questionnaire was designed in order to give a current employment history of each participant including night shift work and heavy lifting. Second part of the questionnaire is used to examining source of the vibration exposure and ergonomic factors. Third part has been included in order to measure how much the drivers were exposed to WBV and it also has been evaluated for the sources different than their occupation. Fourth part comprised general and low back-specific section of the Nordic musculoskeletal questionnaire. Subsequently the fifth section considers the personal details of each participant.

3.2 Sample Sizing

Cross-sectional studies usually categorize as medium or low validity designs, however a high sample size could empower such a study to have a more valid results.

In order to find the minimum required sample size based on type II error (β=0.05), this study used two formula depending on the type of the variables from the questionnaire. Gang (1999) divided variables into two groups, continuous and dichotomous variables. Continuous variable, standard deviation of each variable plays an important role to determine the amount of sample size. On the other hand, dichotomous variables estimate the minimum sample size considering the proportion of the outcomes. Based on the Gang (1999) following two formulas are used to determine the minimum required sample size for this research.

For continuous variables:

$$n = \frac{Z^2 S^2}{d^2} \qquad (3.1)$$

Where:

n is the minimum size of the sample;

Z is the z-statistics for the desired level of confidence;

S is the population standard deviation;

d is the half width of the desired interval;

Depending on the chosen α, Z value could differ. In this study type I error is taken as five percent (α=0.05). Thus according to Z distribution table for α=0.05, Z is equal to 1.96. S is the standard deviation of the population. It is good to mention that, in most cases the standard deviation of population is unknown. So in order to estimate the minimum number of sample first a pilot search is run to collect data and by using the standard deviation of the pilot search this formula can be used to determine the required sample size. In sample, d is evaluating the precision of sample estimation. For this study upper bound minus lower bound of the pilot confidence interval is fixed as the maximum desire interval or d.

For dichotomous variables:

$$n = \frac{Z^2 p(1-p)}{d^2} \qquad (3.2)$$

Where:

n is the minimum size of the sample;

Z is the z-statistics for the desired level of confidence;

P is the expected proportion of the variable of interest

d is the half width of the desired interval;

And q = (1-p);

In second equation instead of standard deviation of the population, the expected proportion is required. Expected proportion is calculated from the pilot search for dichotomous variables. Type II error (β=0.05) has been applied on d for the second equation (Rahman, 2013). It is good to mention that, Type II error occurs when there is not enough evidence to reject the null-hypothesis even though it is false. This means that the sample size is strongly related to type II error.

3.3 Hypotheses

Each hypothesis to be tested is determined based on the literature.

H_1: there is an association between smoking status and discomfort of low back area which has been reported during the last 12 months among truck drivers (Ernst 1993; Kilbom *et al.* 1996).

- To test H_1, chi-square test of independence is appropriate. Independent variables are smoking status (with three levels of smoker, non-smoker and ex-smoker) and low back area discomfort during the last 12 months (with two levels of did experience and did not experience).

H_2: there is an association between weekly hours of exposure to vibration and discomfort of low back area which has been reported during the last 12 months among truck drivers (Bernard and Putz-Anderson, 1997; Bongers *et al.*, 1990; Boshuizen *et al.*, 1990; Bovenzi and Betta, 1994; Bovenzi and Hulshof, 1998; Lings and Leboeuf-Yde, 2000; Magnusson *et al.*, 1996; Mirzaei and Mohammadi, 2010; Sang *et al.*, 2010).

- In order to calculate the weekly hours of exposure to vibration, the estimated occupational weekly driving hours is added to the hours each participant drove other source of vibration (car, van, train, bus and etc.) during the spare time. By classifying the weekly hours of exposure into four levels as below, the weekly exposure time is transformed to categorical data and the chi-square test of independence for H_2 could be applied. The two independent variables related to this claim are, low back area discomfort during the last 12 months (with two level of did experience and did not experience) and hours of exposure with following levels:

  Level 1: Drivers who are not exposed to WBV more than 8 hours of the day in a week (Exposure time <= 56h)

Level 2: Drivers who are exposed to WBV more than 8 hours of the day in a week to 12 hours a day for 7 days of the week (56h < exposure time <= 84)

Level 3: Drivers who exposed to WBV more than 12 hours a day for 7 days of the week to 16 hours a day for 7 hours of the week (84h < exposure time <=112h)

Level 4: Drivers who exposed more than 16 hours a day for 7 days of the week (Exposure time > 112h)

H_3: there is an association between weekly hours of exposure to vibration and discomfort of neck area which has been reported during the last 12 months among drivers (Bernard and Putz-Anderson, 1997; Bovenzi and Hulshof, 1998; Wikström *et al.*, 1994).

H_4: there is an association between weekly hours of driving and discomfort of shoulders area which has been reported during the last 12 months among drivers (Bernard and Putz-Anderson, 1997; Bovenzi and Hulshof, 1998; Wikström *et al.*, 1994).

- The same pattern of H_2 can be considered for H_3 and H_4

H_5: Most of the drivers experience Low back discomfort during the last 12 months (Robb and Mansfield, 2007).

- Using single proportion binomial test for H_5 (H_0: proportion = 0.5) would be appropriate where the dependent variable is the percent of participant who experienced ache pain or any discomfort during the last 12 months in low back area.

H_6: there is an association between night shift and BMI (Moreno *et al.*, 2006).

- Dividing BMI into four subcategories would transform this variable to categorical data. According to Nazerian *et al.* 2015 there are four categories named as underweight (BMI<18), Normal-range (18<BMI<25), overweight (25<BMI<30) and obese (BMI>30). After this division chi-square test of independence could be consider to test H_6.

H_7: there is an association between BMI and discomfort of low back area which has been reported during the last 12 months among drivers (Raanaas and Anderson, 2008).

- Chi square test of independence would be appropriate for H_7

H_8: there is an association between age of the drivers and number of musculoskeletal discomfort which has been reported by each driver during the last 12 months (Gangopadhyay *et al.*, 2012; Kilbom *et al.*, 1996).

- According to Affairs (1982) the age data is categorized by following path: less than 25 years old, 25-35, 35-45, 45-55, 55-65, more than 65 years old. This categorization would convert the age factor from numeric to categorical data. Subsequently in order to test H_8, chi-square test of independent is appropriate.
- The questionnaire divided the human body in to 12 region named as neck, left shoulder, right shoulder, left elbow, right elbow, left wrist, right wrist, upper back, lower back, hips, knees and ankles. Each driver individually is asked whether he had any ache, pain or discomfort in any specific mentioned body parts during the last 12 months or not. Counting the number of reported discomfort for each participant would give a number between 0 to 12 parts. This

number is equals to the number of body part each driver has experienced discomfort during the last 12 months.

- To test H8, analysis of variances (one way ANOVA) is appropriate. The independent variable (6 age subcategories as mentioned above) is categorical and the dependent variable (number of body part they have discomfort during the last 12 month) is numerical data.

H_9: There is a significant association between the intensity of the low back discomfort during the worst episode and hours that truck drivers are being prevented form work (Robb and Mansfield, 2007).

- To test H_9, chi-square test of independence is appropriate. Independent variables are intensity of LBP (in three levels of mild, severe and very severe) and prevention time (in four level of 0, 1-7, 8-30 and more than 30 days).

H_{10}: there is a significant relation between drivers who experience accident and the number of body part they have experienced musculoskeletal discomfort during last 12 months (Robb and Mansfield, 2007).

- To test H_{10}, analysis of variances (one way ANOVA) is appropriate. The independent variable (whether they had an accident or not) is categorical and the dependent variable (number of body part they have discomfort during the last 12 month) is numerical data.

H_{11}: weekly hours of exposure to vibration is significantly associated with the number of body part which truck drivers have experienced musculoskeletal discomfort during last 12 months (Robb and Mansfield, 2007).

- The one way ANOVA is applicable for testing H_{11} as well.

The last three hypotheses are being chosen in order to have a better coverage on the questionnaire of the study.

H_{12}: There is a significant association between seat comfort and discomfort of neck area which has been reported during the last 12 months among drivers

- Seat comfort is a scale from 1 to 7 (7 is the most comfortable seat). Chi-square test of independence is applicable on this hypothesis. The two independence variables are seat comfort (in 7 levels) and discomfort of neck area experienced during the last 12 months in 2 levels.

H_{13}: There is a significant association between seat comfort and discomfort of shoulders area which has been reported during the last 12 months among drivers.

- Chi-square test of independence is applicable on this hypothesis. The two independence variables are seat comfort (in 7 levels) and discomfort of neck area experienced during the last 12 months (in 3 levels of neither of the shoulders, right shoulder and left shoulder)

H_{14}: There is a significant association between seats with easy to adjusted lumber support and discomfort of low back area which has been reported during the last 12 months among truck drivers.

- Chi-square test of independence is applicable on this hypothesis. The two independence variables are easy to adjusted lumber support (in two levels of whether it has or not) and discomfort of low back area experienced in last 12 months (in two levels of whether the participants experienced discomfort or not).

Table 1: Questions related to each hypothesis

Hypothesis	*Related questions*
H_1	5f, 4a (7th row & 2nd column)
H_2	3a+3e, 4a (7th row & 2nd column)
H_3	3a+3e, 4a (3rd row & 2nd column)
H_4	3a+3e, 4a (7th row & 2nd column)
H_5	4a (7th row & 2nd column)
H_6	5c/$(5d)^2$, 1e(iii)
H_7	5c/$(5d)^2$, 4a (7th row & 2nd column)
H_8	5a, number of reported discomfort in second column of table 4a
H_9	4f, 4i
H_{10}	4c, number of reported discomfort in second column of table 4a
H_{11}	3a+3e, number of reported discomfort in second column of table 4a
H_{12}	2e,4a(2nd row & 2nd column)
H_{13}	2e,4a(3rd row & 2nd column)
H_{14}	2e, 4a (7th row & 2nd column)

Table 1 addresses the hypotheses to the related questions in the questionnaire in order to track the results in a better way.

3.4 Data Analysis

This cross sectional study is applied in Iran. All the data has been collected randomly in the customs stations in deferent states, where the heavy truck driver gathers in distant line to loud up or off their truck and head towards other destinations.

All of the questionnaires have been field by face to face interview. The drivers were explained that the answers they provide will be confidential, and they were not exposed to any danger or harm upon answering these questions. Thus, their consent was collected before interview. A brief explanation also has been prepared about the purpose of the study and presented to each interviewee individually. Moreover, all the participants are informed that they have the right to cancel the process at the beginning or during the interview.

A pilot search of 48 participants is done at the beginning of the data collection in the first day. After that, sample size is formulas (3.1) & (3.2). Thereafter, in order to prevent the regional effect on the study, minimum sample size of the study is collected in four different region of the country.

3.4.1 Questionnaire Validation

According to Carlson and Morrison (2009) cross sectional studies have low validity regarding to their vast implications. However, in cross sectional studies the purpose is to track multiple factors for multiple effects. Therefore, this type of research is mostly for creation of hypotheses to be tested in more valid studies in future studies. Table 2 illustrates a comparison of different study designs and their properties (Carlson and Morrison, 2009).

As Table 2 shows, cross-sectional studies are belong to observational study design. Internal and external validity are the keys to determine the validation of this the questionnaire which is used in this particular research.

As Table 2 shows, cross-sectional studies are belong to observational study design. Internal and external validity are the keys to determine the validation of this the questionnaire which is used in this particular research.

Internal validity stands for strength of inferences in the research. For better understanding of this concept, whenever the internal validity of a study is low, it is less accurate to conclude that the exposure of a factor causes an particular outcome. As well, this study only investigates the association of different factors not the cause.

Table 2: Observational and Experimental study designs and their properties

	Experimental	*Observational*		
Study design	Randomized Control Trail	Cross-sectional	Cohort	Case-control
Study population	Highly selected population; highly controlled environment	Diverse population observed in a range of settings	Diverse population observed in a range of settings	Diverse population observed in a range of settings
Primary Use	Demonstrating efficacy of an intervention	Screening hypotheses; prevalence studies	Assessing association between multiple exposures and outcomes over time	Assessing associations between exposures and rare outcomes
Internal validity	High	Low	Low	Low
External validity	Low-moderate	High	High	High

On the other hand external validity is the power to establish the results to a more universal population. In other words, external validity is the measurement tool to determine how much the conclusion of a study could be correct for other time and places.

It is good to mention that the studies related to WRMSDs are mostly cross-sectional or case-control type and comparing to prospective cohort studies these types of researches has lower validity. However, these methods are well established and have been validated in many areas including physical efforts (Borg and Kaijser, 2006), acoustics (Kuwano and Namba, 1985) and musculoskeletal stresses (Arvidsson *et al.*, 2006; McGill and Brown, 2005).

Consequently, even though cross-sectional studies have low internal validity, they are a good survey to generate lots of outcomes and hypotheses for future consideration.

3.5 Regression Analysis

Regression analyses are illustrated in order to assess the association of musculoskeletal discomfort questions and other questions of the questionnaire. The regression model contains a dependent variable or outcome which is correlated with other independent variables or predictors. Subsequently a model is created for each outcome.

The dependent variables are considered as *Y*s. The basic purpose of using regression method in this research is to investigate the predictor risk factors for musculoskeletal discomfort; therefore, musculoskeletal discomforts are the dependent variables. Table 3 shows the related questions of the questionnaire for each dependent variables and regression model. It is good to mention that the following questions are the paraphrased version of the questionnaire. Related questions in the questionnaire are in part 4 a Table.

According to Table 3, not any of the variables are linear; therefore, binary logistic regression is used for dichotomous variables and multinomial logistic regression is used for categorical variables.

In Binary logistic regression the goal is to estimate the probability of dependent variable to be 1 ($\hat{p}$). This number represents the answer of “Yes” regarded to the dependent variable or question (Y_i). In order to link the linear combination of the predictors with the probability function of dependent variable, the natural log of odds ratio is used to create the link. This function is represented in Formula 3.3.

Table 3: Dependent variables and related questions for regression

Variable	*Related question*	*distribution*
Y_1	Have you had discomfort in any part of your body during last12 months?	dichotomous
Y_2	Have you had discomfort in in neck area during last12 months?	dichotomous
Y_3	Have you had discomfort in shoulders area during last12 months?	Categorical
Y_4	Have you had discomfort in your elbows during last12 months?	Categorical
Y_5	Have you had discomfort in your wrists during last12 months?	Categorical
Y_6	Have you had discomfort in upper back area during last12 months?	dichotomous
Y_7	Have you had discomfort in lower back area during last12 months?	dichotomous
Y_8	Have you had discomfort in buttocks area during last12 months?	dichotomous
Y_9	Have you had discomfort in your knees during last12 months?	dichotomous
Y_{10}	Have you had discomfort in your ankles during last12 months?	dichotomous
Y_{11}	Have you had discomfort in any part of your body during last 7 days?	dichotomous
Y_{12}	Have you had discomfort in in neck area during last 7 days?	dichotomous
Y_{13}	Have you had discomfort in shoulders area during last 7 days?	dichotomous
Y_{14}	Have you had discomfort in your elbows during last 7 days?	dichotomous
Y_{15}	Have you had discomfort in your wrists during last 7 days?	dichotomous
Y_{16}	Have you had discomfort in upper back area during last 7 days?	dichotomous
Y_{17}	Have you had discomfort in lower back area during last 7 days?	dichotomous
Y_{18}	Have you had discomfort in buttocks area during last 7 days?	dichotomous
Y_{19}	Have you had discomfort in your knees during last 7 days?	dichotomous
Y_{20}	Have you had discomfort in your ankles during last 7 days?	dichotomous

- $\ln\left(\frac{\hat{p}}{1-\hat{p}}\right) = \beta_0 + \sum_i \beta_i X_i$ (3.3)
- Where:
- *$\hat{p}$ is the Probability of $Y = 1$*
- *i* is the number of predictors
- *β_0 is the constant*
- *β_i is the i^{th} predictor variable coefficient*

In order to have the p̂ in one side of the equation, following algebra calculation is needed:

- Antilog the equation: $\frac{\hat{p}}{1-\hat{p}} = e^{(\beta_0 + \sum_i \beta_i X_i)}$ (3.5)

- Both sides multiplied by $(1-\hat{p})$: $\hat{p} = e^{(\beta_0+\sum_i \beta_i X_i)}.(1-\hat{p})$ (3.6)
- Distribute $(1-\hat{p})$: $\hat{p} = e^{(\beta_0+\sum_i \beta_i X_i)} - \hat{p}.e^{(\beta_0+\sum_i \beta_i X_i)}$ (3.7)
- Move all the $\hat{p}$ to left side: $\hat{p} + \hat{p}.e^{(\beta_0+\sum_i \beta_i X_i)} = e^{(\beta_0+\sum_i \beta_i X_i)}$ (3.8)
- Factor $\hat{p}$ from right: $\hat{p}(1 + e^{(\beta_0+\sum_i \beta_i X_i)}) = e^{(\beta_0+\sum_i \beta_i X_i)}$ (3.9)
- Final equation: $\hat{p} = \frac{e^{(\beta_0+\sum_i \beta_i X_i)}}{(1+e^{(\beta_0+\sum_i \beta_i X_i)})}$ (3.10)

Predictor of the regression models are chosen by Pearson's correlation method. Questions which have the p-value of less than 0.05 in the Pearson's correlation matrix are considered as predictors. P-value of Wald test would determine whether the predictor should or should not be in the equation. Whenever this p-value is less than 0.05, the predictor considers as one of the variables (X_i) in the right hand side of the regression equations. Subsequently, by using equation 3.10, the probability of Y_i=1can be estimated.

Related to multinomial logistic regressions it should be mentioned that, because the dependent variable is categorical and contains more than two levels, therefore one level would be considered as the reference and others are compared to this level. For example, if a categorical dependent variable contains four levels of "1", "2", "3" and "4", one of them is considered as the reference and subsequently for other levels there are equations respectively. Each equation follows the binary equation of 3.10; however, in these cases the $\hat{p}$ is the probability of that level happening instead of reference level.

Finally it should be mentioned that all the calculations related to hypotheses and regression equations are done by SPSS software.

3.6 REBA Analyses

Three postures are selected during the interviews. By observing regular job process of the occupational drivers these postures are selected based on the most awkward, most weight handled and most constant positions. Related to each of these positions, the total scores are calculated by the worksheet of REBA; and then after, Improvements are applied for each of them separately. These improvements are based on the purpose of the postures in a way that there would be no limitation for actual processes.

Five REBA score category is adjusted for this method:

- First, when the score is equal to 1. This category requires no changes since the risk is negligible.
- Second, REBA scores which are 2 and 3. In this scenario, changes may be needed because of the low risk.
- Third, the REBA scores between 4 and 7. In these cases, further investigations are needed and the position must be changed soon.
- Fourth, the REBA scores which are between 8 and 11. For this category, the position must be investigated and changes must be implemented; because, it stands for high risk positions.
- Last, the REBA scores which are more than or equal to 11. These types of positions are known as very high risk and therefore, changes must be implemented immediately.

Finally the comparisons between the primary and improved postures are done based on the total scores.

Chapter 4

RESULTS

4.1 Sample Size Testing

As it is explained in section 3.4, a pilot search has been applied for determining the minimum required sample size for this research.

Table 4: Hypotheses related variables and minimum required sample size

Variables	***n***	***Type of data***	***SD***	***P(1-P)***	***Sample size***
Hours of exposure to vibration	47	Continuous	38.70		230.2
BMI	47	Continuous	5.54		4.7
Amount of discomfort reported	47	Continuous	2.73		1.1
Age	47	Continuous	11.62		20.7
Night shift	47	Dichotomous		0.095	146.1
Accident	30	Dichotomous		0.000	0
Lumber Support	47	Dichotomous		0.250	384.0
Discomfort reported for last 12 months					
Lower back area	47	Dichotomous		0.244	375.6
Neck	47	Dichotomous		0.247	379.8
Left shoulder	47	Dichotomous		0.249	382.6
Right shoulder	47	Dichotomous		0.241	370.1

Table 4 proposes the detailed of the outcomes of the pilot search for different variables which has been used for testing the fourteen hypotheses of the study. Among different estimation in Table 4, the maximum required sample size belongs to dichotomous variable of lumber support. So in order to eliminate the Type II error for this study remaining 337 is completed by male drivers.

4.2 Questionnaire Findings

Regarding to minimum sample size of participants, 384 male heavy truck drivers are interviewed by the questionnaire. In the following paragraphs some statistic information about the prevalence of musculoskeletal disorder is explained.

4.2.1 First Part of the Questionnaire Findings

All of the participants were currently employed during the interview and their main occupation was “driver”. Moreover, related to first part of the questionnaire Table 5 shows the finding results with regard to answers of the participants.

Table 5: Findings related to first part of the questionnaire

Sub-categories	Frequency	(%)	Cumulative percent
In what industry did you carry out this occupation (Driver)?			
Construction	33	8.6	8.6
Multi-industries	228	59.4	68.0
Automotive manufacturing	40	10.4	78.4
Petrochemical	25	6.5	84.9
Military	6	1.6	86.5
Cosmetic	5	1.3	87.8
Automotive parts manufacturing	45	11.7	99.5
Agricultural	2	0.5	100.0
Total	384	100.0	100.0
Does an average day involve lifting weight of 10Kg or more?			
Yes	384	100.0	100.0
No	0	0.0	100.0
Total	384	100.0	100.0
Does an average day involve lifting weight of 25Kg or more?			
Yes	384	100.0	100.0
No	0	0.0	100.0
Total	384	100.0	100.0
Does an average day involve working in night shift?			
Yes	343	89.3	89.3
No	41	10.7	100.0
Total	384	100.0	100.0

According to Table 5, without any exception all the participants lift weights more than 25 Kg in their daily jobs. During the interview most of them claim that this activity mostly originating from maintenance operations of the truck such as lifting tool box, spare tire and heavy tools. Drivers who were not employed in a certain industry and accept any transportation jobs, counted as multi-industry occupational driver in the table.

4.2.2 Second Part of the Questionnaire Findings

Table 6: Findings related to second part of the questionnaire

Sub-categories	Frequency	(%)	Cumulative percent
Model of the truck			
Mack	78	20.3	20.3
Volvo	126	32.8	53.1
Renault	4	1.0	54.2
Benz	96	25.0	79.2
Unknown	80	20.8	100.0
Total	384	100.0	100.0
Does the vehicle have a suspension seat?			
Yes	339	88.3	88.3
No	45	11.7	100.0
Total	384	100.0	100.0
Is the chair easy to adjust?			
Yes	326	84.9	84.9
No	58	15.1	100.0
Total	384	100.0	100.0
Does the chair have armrest?			
Yes	33	8.6	8.6
No	351	91.4	100.0
Total	384	100.0	100.0
Does the chair have easy to adjusting lumber support?			
Yes	188	49.0	49.0
No	198	51.0	100.0
Total	384	100.0	100.0

4.2.3 Third Part of the Questionnaire Findings

Table 8 illustrates the descriptive properties of data related to usage of different transportation ways which drivers use in their spare time. All the units in this table are hours which have been estimated by drivers.

Table 7: Seat comfort results

Sub-categories	Frequency	(%)	Cumulative percent
How comfortable do find your seat?			
Dramatically uncomfortable	15	3.9	3.9
Very uncomfortable	55	14.3	18.2
Uncomfortable	66	17.2	35.4
Normal	78	20.3	55.7
Comfortable	69	18.0	73.7
Very comfortable	84	21.9	95.6
Extremely comfortable	17	4.4	100.0
Total	384	100.0	100.0

Table 8: Spare time transportation system

					95% CI	
	n	Mean	SD	Std. error	Lower bound	Upper bound
Car or van	69	12.19	9.95	0.72	10.76	13.62
Train	75	12.04	5.84	0.67	10.70	13.38
Bus or coach	67	11.82	6.54	0.80	10.22	13.42
Motorcycle	71	13.39	6.49	0.77	11.86	14.93
None	102	-	-	-	-	-
Total	384	9.08	7.62	0.39	8.32	9.85

Table 9 also demonstrates the hours that drivers are exposed to vibration in a week; it is good to mention that related to this table the question was as follow: What is the total number of hours that you drove / rode / stood on the truck in a week (only the times when the engine was running)?

Table 9: Approximate hours drove by drivers in a week

Sub-categories	Frequency	(%)	Cumulative percent
Less than 48	51	13.3	13.3
Between 48 h - 56 h	14	3.6	16.9
Between 56 h - 84 h	137	35.7	52.6
Between 84 h - 112 h	126	32.8	85.4
More than 112 h	56	14.6	100.0
Total	384	100.0	100.0

The categories of the Table 9 have been explained in the methodology chapter.

4.2.4 Fourth part of the questionnaire findings

The prevalence of musculoskeletal discomfort among these drivers is presented in Figure 1.

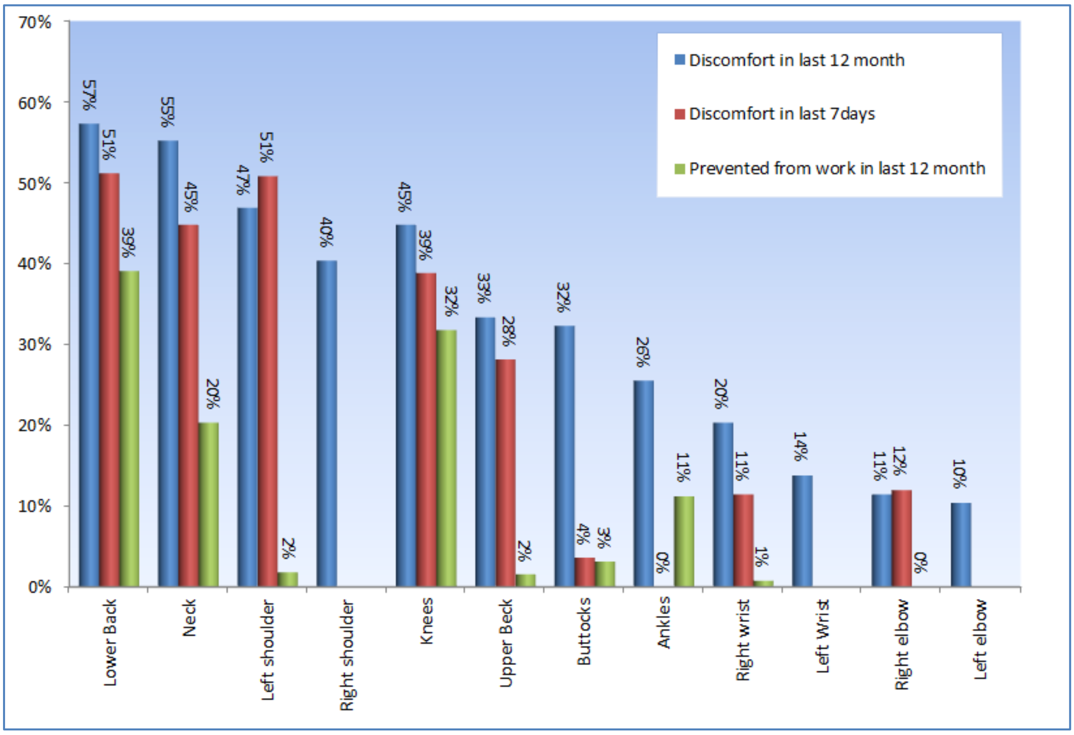

Figure 1: Main prevalence chart of the study

The blue color in Figure 1 shows the prevalence of discomfort during the last 12 months which are reported by truck drivers. Among these body parts 57% of participants had experienced discomfort in their low back area which is the highest prevalence in this study. After that, 55% of the drivers experienced discomfort in neck area which put this part in the second place in the chart. Subsequently, left shoulder (47%), knees (45%), right shoulder (40%), upper back (33%), buttocks (32%), ankles (26%), right wrists (20%), left wrist (14%), right elbow (11%) and left elbow (10%) are the rest outcomes of the chart. No driver reported trouble in ankle area for last 7 days.

The red color in this figure demonstrates the prevalence of musculoskeletal discomfort during the last 7 days. In this scale of time, Shoulders and lower back area have the highest prevalence among others (51%). The rest of the data are as follow: neck (45%), knees (39%), Upper back (28%), elbows (12%), Wrists (11%) and Buttocks (4%).

At last, the green light stands for amount of drivers who has been prevented from doing the normal activity of the job regarded to the area which they had pain or discomfort. At most discomfort in the lower back area has been reported as the cause of prevention (39% of the participants) and after that knees (32%), neck (20%) and ankles (11%) was the reasons for not being able to do the job among drivers. Less than 5% of participants caused other areas to which had prevented them from doing their job.

Table 10 clarifies the rest of the questions findings related to the fourth part of the questionnaire. It is good to mention that in this part, drivers who did not had any trouble in their low back area, escaped the questions and answered the fifth part of the questionnaire. Thus, less than 384 drivers answered these questions.

Related to low back trouble, only 7 drivers (3.1%) caused their LBP to an accident which they had experienced in past. And among these 7 drivers, 4 of them (57.1) had the accident while they were at work.

Between 221 drivers who had low back trouble, only one driver changed his job because of the pain.

Table 10: Lower back specific results

Sub-categories	Frequency	(%)	Cumulative percent
Have you had any Low back trouble at all?			
No	157	40.9	40.9
Yes	227	59.1	100.0
Total	384	100.0	100.0
How bad was the LBP during the worst episode?			
Mild	22	9.7	9.7
Severe	120	52.9	62.6
Very, very severe	85	37.4	100.0
Total	227	100.0	100.0
What was the total length of time that you had low back trouble during last 12 months?			
0 day	21	19.4	19.4
1-7 days	20	18.5	38.0
8-30 days	23	21.3	59.3
More than 30 days	21	19.4	78.7
Every day	23	21.3	100.0
Total	108	100.0	100.0
What was the total length of time that you had prevented from work because of low back trouble?			
0 day	155	70.1	70.1
1-7 days	32	14.5	84.6
8-30 days	16	7.2	91.9
More than 30 days	18	8.1	100.0
Total	221	100.0	100.0
Have seen a doctor for your low back trouble?			
Yes	107	51.4	51.4
No	113	48.6	100.0
Total	220	100.0	

The last question of this part is as follow:

“Please give details of any issues regarded to vibration and back pain that have not been discussed by his questionnaire:”

Following answers are collected during the interview:

Lower salary which cause more of working by 15 drivers (6.78%)

Speed bumps by 77 drivers (34.8%)

Bumpy roads by 6 drivers (2.7%)

others (58.4%) did not had any comment related to this question

4.2.5 The fourth part of the questionnaire findings

Tables 11 and 12 explain all the findings related to the last part of the questionnaire.

Table 11: Demographical outcomes (numeric)

	n	Mean	SD	Std. error	Minimum	Maximum
Age (year)	384	43.80	10.99	0.561	20	70
Weight (Kg)	384	81.33	14.49	0.739	43	150
Height (m)	384	1.74	0.12	0.006	1.45	1.98
BMI (Kg/m^2)	384	27.12	5.03	0.256	15.03	48.98

4.1 Hypothesis Test Results

In this chapter the following results are clarified with regarded to 14 hypotheses which demonstrated in methodology chapter.

4.1.1 H_1 Results

In order to check H_1, Table 13 is demonstrated. This table is the cross tab of two independent variables smoking status with 3 and lower back discomfort with 2 level.

As there is no expected value less than or equal 5, chi-square test of independence is used to determine whether there is a significant association or not.

Results related to the hypothesis are as follows:

- Chi-square value = 0.414
- Degree of freedom = 2
- P-value = 0.813

Table 12: Demographical outcomes (nominal)

Sub-categories	Frequency	(%)	Cumulative percent
Gender			
Male	384	100.0	100.0
Female	0	0.0	100.0
Total	384	100.0	100.0
Handedness			
Right handed	335	87.2	87.2
Left handed	44	11.5	98.7
Both handed	5	1.3	100.0
Total	384	100.0	100.0
Smoking status			
Smoker	253	65.9	65.9
None-smoker	106	27.6	93.5
Ex-smoker	25	6.5	100.0
Total	384	100.0	100.0

Table 13: Cross tab table for H_1

			Low back discomfort (last 12 months)		
			No	Yes	Total
Smoking status	Smoker	Observed	111	142	253
		Expected	108.1	144.9	253.0
	Non-smoker	Observed	43	63	106
		Expected	45.3	60.7	106.0
	Ex-smoker	Observed	10	15	25
		Expected	10.7	14.3	25.0
	total	Observed	164	220	384
		Expected	164.0	220.0	284.0

As the p-value is greater than 0.05, there is not enough evidence to reject the null-hypothesis; therefore, H_1 cannot be accepted.

4.1.2 H_2 Results

The second cross tab in Table 14 is for investigation of association between hours of exposure to vibration and low back discomfort during last 12 month. The same as Table 13, Table 14 does not have any expected value less than or equal to 5.

Therefore, chi-square test of independence is used to determine the association of these variables. Following results are achieved for H_2:

- Chi-square value = 3.639
- Degree of freedom = 3
- P-value = 0.303

As the p-value is greater than 0.05, there is not enough evidence to reject the null-hypothesis and H_2 cannot be accepted.

Table 14: Cross tab table for H_2

			Low back discomfort (last 12 months)		
			No	Yes	Total
Hours of exposure to vibration	Less than 56h	Observed	18	29	47
		Expected	20.1	26.9	47
	56 – 84 h	Observed	46	74	120
		Expected	51.3	68.8	120
	85 – 112h	Observed	59	60	119
		Expected	50.8	68.2	119
	More than 112h	Observed	41	57	98
		Expected	41.9	56.1	98
	Total	Observed	164	220	384
		Expected	164	220	384

4.1.3 H_3 Results

With regard to H_3, Table 15 illustrates the cross tab with two independent variables of hours of exposure to vibration and neck discomforts which are reported by participants for the period of 12 months. As Table 15 shows, there is no expected value less than or equal to 5. Thus, chi-square test of independence is appropriate for this hypothesis. Outcome of chi-square test is as follows:

- Chi-square value = 54.568

- Degree of freedom = 3
- P-value = 0.000

Table 15: Cross tab table for H_3

Hours of exposure to vibration			Neck discomfort (last 12 months) No	Yes	Total
	Less than 56h	Observed	34	13	47
		Expected	21.1	25.9	47
	56 – 84 h	Observed	75	45	120
		Expected	53.8	66.3	120
	85 – 112h	Observed	41	78	119
		Expected	53.3	65.7	119
	More than 112h	Observed	22	76	98
		Expected	43.9	54.1	98
	total	Observed	172	212	384
		Expected	172	212	384

The p-value related to this test is less than 0.05; thus, the null-hypothesis is rejected; and therefore H_3 is true. Moreover, for investigating this association graphically, Figure 2 is illustrated.

Figure 2 shows the answers given to neck problem related to different hours of exposure to vibration. As the hours of exposure increase, more neck problems are reported. Even though, the height of green column for exposure less than 56h is lower than green column for exposure between 56 – 84 h, there was not a significant increase in neck problem. This difference of height is originating from different sample sizes. In order to prevent confusion of unbalance bar charts instead of count for Y-axis in Figure 2, in Figure 3, Y-axis illustrates the percentage of each outcome related to each category of X-axis.

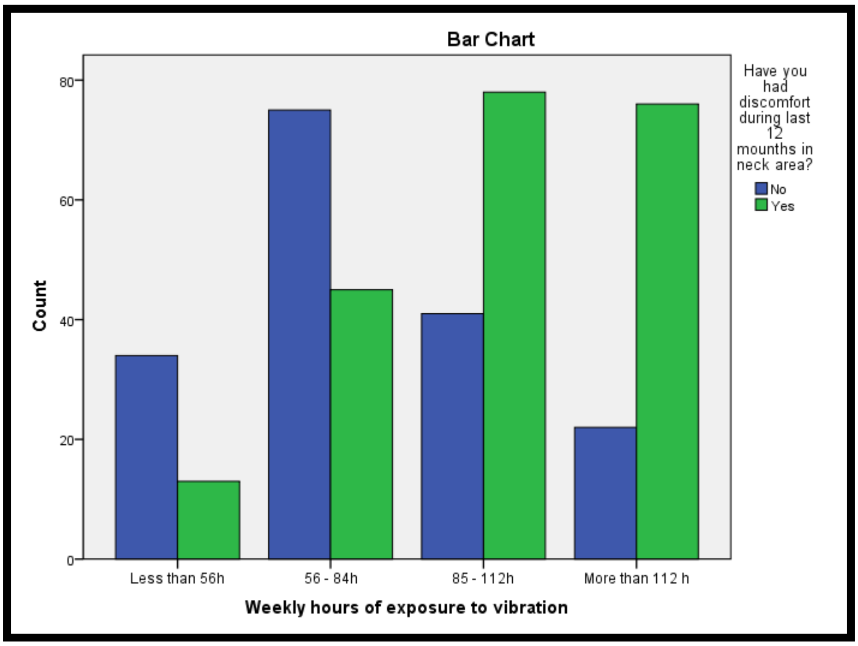

Figure 2: Bar chart of H_3 (count)

Figure 3 avoids any misunderstanding which could cause by unbalanced sample sizes; therefore, for the following hypothesis results, this method is used to construct bar charts.

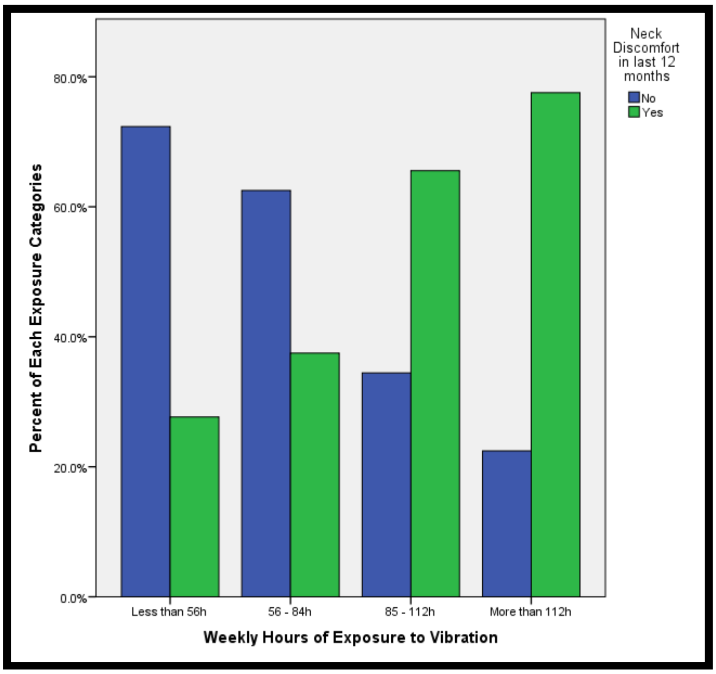

Figure 3: Bar chart of H_3 (percentage)

4.1.4 H_4 Results

Table 16 demonstrates the cross tabs related to two independent variable of H_4.

Table 16: Cross tab table for H_4

			Shoulder discomfort (last 12 months)			
			No	Yes in one shoulder	Yes in both shoulder	Total
Hours of exposure to vibration	Less than 56h	Observed	15	25	7	47
		Expected	17	19	11	47
	56 – 84 h	Observed	58	41	21	120
		Expected	43.4	48.4	28.1	120
	85 – 112h	Observed	50	38	31	119
		Expected	43.1	48	27.9	119
	More than 112h	Observed	16	51	31	98
		Expected	35.5	39.6	23	98
	total	Observed	139	155	90	384
		Expected	139	155	90	384

There is no expected value less than or equal to 5 in Table16. Thus, chi-square test of independence is appropriate for this hypothesis.

Results of the H_4 are as follows:

- Chi-square value = 31.811
- Degree of freedom = 6
- P-value = 0.000

Chi-square test shows a significant association between hours of exposure to vibration and shoulder discomfort (p-value < 0.05). In order to understand the behavior of this association, Figure 4 is established.

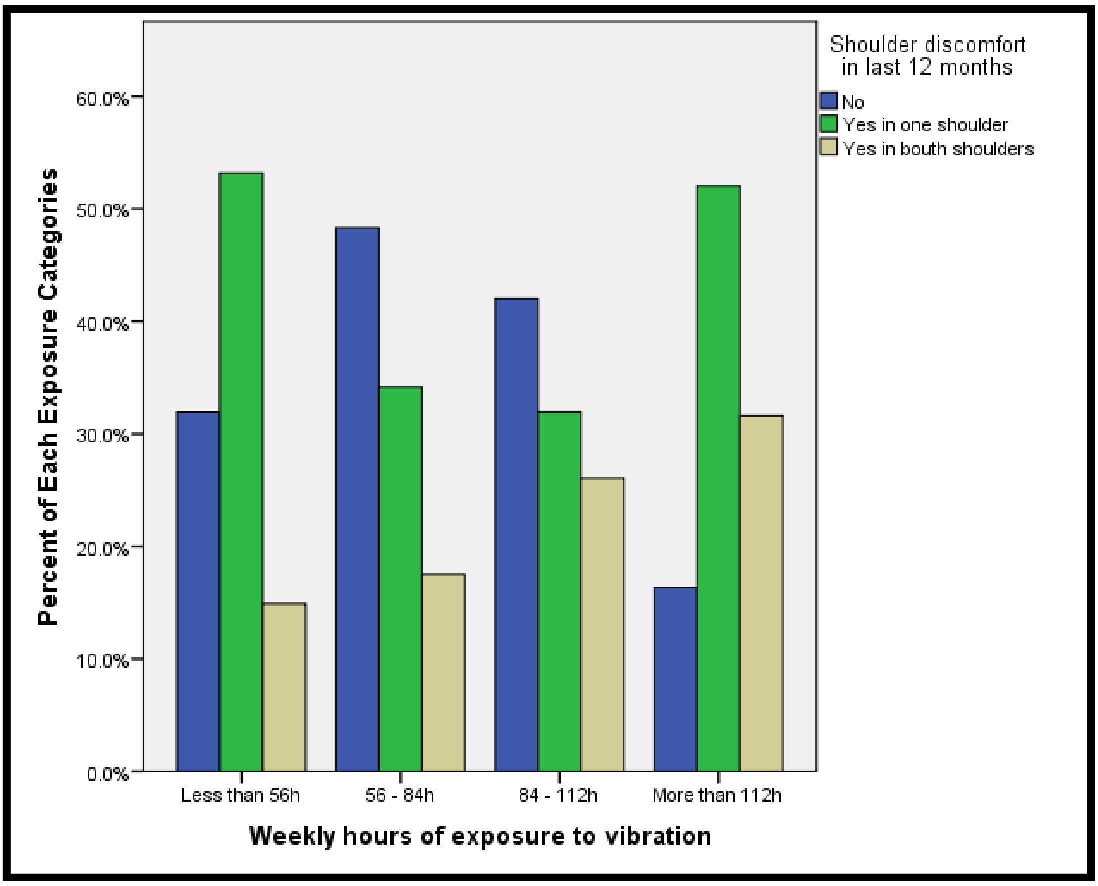

Figure 4: Bar chart of H_4 (percentage)

According to Figure 4, by the increase of hours of exposure to vibration, reports of shoulder discomfort goes up. Drivers who were exposed to vibration less than 56h weekly were not in this trend.

4.1.5 H_5 Results

To test H_5 binomial proportion test is applied with p (proportion) = 0.5. Estimated p is used from Figure 1 for low back discomfort in last 12 months ($\hat{p}$ = 0.57). Therefore, outcome shows a significant evidence of rejecting the null-hypothesis (p-value=0.001); thus, Most of the drivers experience Low back discomfort during the last 12 month; and therefore, H_5 is correct.

4.1.6 H_6 Results

Table 17 illustrates the cross tab related to H_6. This table contains of two variables of BMI and night shift work.

Table 17: Cross tab table for H_6

			Do you work on night shifts?		
			No	Yes	Total
BMI	Underweight	Observed	1	10	11
		Expected	1.2	9.8	11
	Normal rage	Observed	21	110	131
		Expected	14	117	131
	Overweight	Observed	9	128	137
		Expected	14.6	122.4	137
	Obese	Observed	10	95	105
		Expected	11.2	93.8	105
	total	Observed	41	343	384
		Expected	41	343	384

As Table 17 clarifies, one cell has the expected value of 1.2; and it is against the assumption of chi-square test of independence. Therefore, instead of using chi-square, fisher's exact test is appropriate for H_6. Results for fisher's exact test related to H_6 are as follows:

- Fisher's exact value = 6.283
- P-value = 0.084

The p-value is greater than 0.05; therefore, there is not enough evidence to reject the null. Thus, H_6 cannot be accepted.

4.1.7 H_7 Results

To test H_7 Table 18 shows the cross tab related to independent variables of the test. Table 18 has an expected value less than 5. Thus, Fisher's exact test is applied for H_7. Outcomes of Fisher's exact test related to H_7 are as follows:

- Fisher's exact value = 38.789
- P-value = 0.000

Table 18: Cross tab table for H_7

			Low back discomfort (last 12 months)		
			No	Yes	Total
BMI	Underweight	Observed	8	3	11
		Expected	4.7	6.3	11
	Normal rage	Observed	72	59	131
		Expected	55.9	75.1	131
	Overweight	Observed	64	73	137
		Expected	58.5	78.5	137
	Obese	Observed	20	85	105
		Expected	44.8	60.2	105
	total	Observed	164	220	384
		Expected	164	220	384

Because the p-value is smaller than 0.05, the null-hypothesis related to H_7 is rejected; and therefore, H_7 is accepted. In order to understand the association of BMI and low back discomfort, Figure 5 is illustrated.

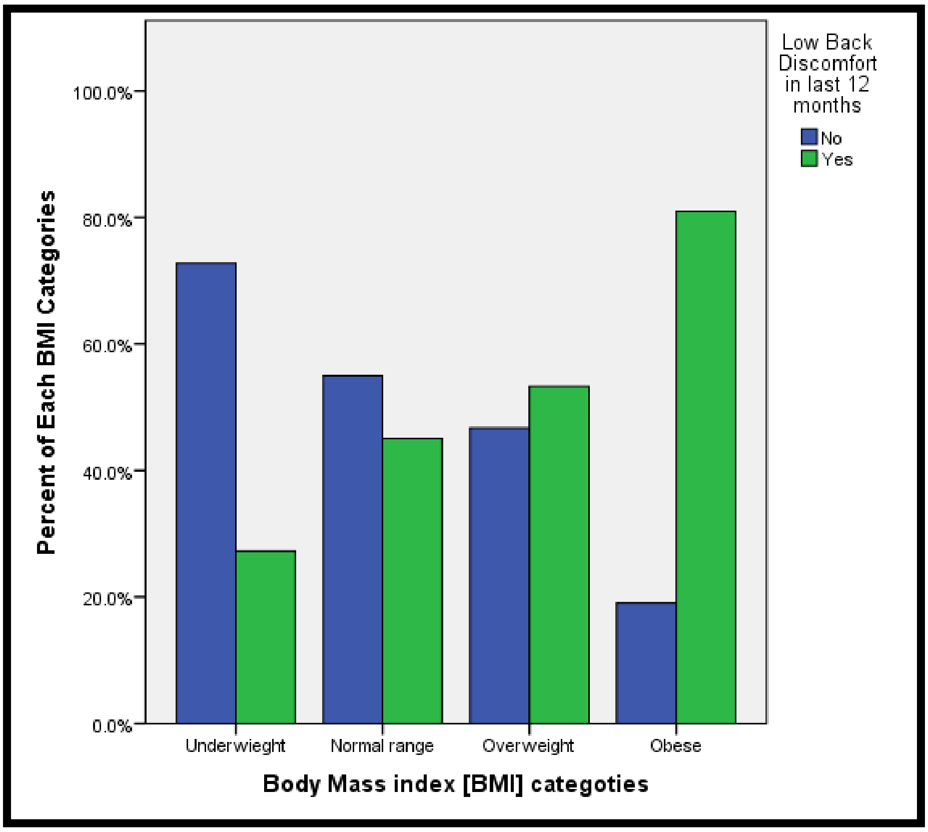

Figure 5: Bar chart of H_7 (percentage)

Figure 5 clarifies a higher prevalence of low back discomfort as BMI increases; however, this increase is not very high between normal range and overweight categories. It is good to mention that in underweight category there is a huge reduction of low back related discomfort among drivers and as it is illustrated in Table 17, only 11 drivers are in this category and it might have an effect on this decrease.

4.1.8 H_8 Results

Table 19 demonstrates a descriptive perspective of H_8. According to related description of this hypothesis in previous chapter, one of the assumptions of ANOVA is the equality of the variances. Therefore, Levene test results are in Table 20. As the p-value of this test is less than 0.05, one of the assumptions of ANOVA is not fit to this test. Welch and Brown-Forsythe tests do not require such assumption. Therefore, to test the equality of means between groups, Welch and Brown-Forsythe tests are used in Table 21.

Table 19: Descriptive table for H_8

Age	n	Mean	SD	Std. error	Minimum	Maximum
Less than 25	20	2.45	1.820	0.407	0	7
25 – 35	73	2.45	1.993	0.233	0	10
35 – 45	125	2.93	1.872	0.167	0	7
45 – 55	117	4.78	1.862	0.172	1	10
55 – 65	38	6.68	2.858	0.464	0	11
More than 65	11	8.82	1.601	0.483	5	11
Total	384	3.92	2.543	0.130	0	11

Table 20: Leven test for H_8

Levene statistic	**Df 1**	**Df 2**	**p-value**
3.825	5	378	0.002

According to Table 21, both tests have the p-value less than 0.05; therefore, the alternative H_8 is accepted. For determining which levels of dependent variable in H_8

are significant from others, Fisher Least Significant Difference (LSD) summaries of results are illustrated in Table 22 and 23.

Table 21: Results of Welch and Brown-Forsythe tests for H_8

	Statistic	**Df1**	**Df2**	**p-value**
Welch	48.10	5	64.892	0.0000
Brown-Forsythe	45.94	5	154.902	0.0000

Table 22: LSD test for mean difference

Age (i)	*Age (j)*	*Mean difference (i-j)*	*Std. error*	*P-value*
	25 – 35	-0.002	0.505	0.997
	35 – 45	-0.478	0.482	0.322
Less than 25	*45 - 55*	-2.328	0.484	0.000
	55 – 65	-4.234	0.553	0.000
	More than 65	-6.368	0.751	0.000
	Less than 25	0.002	0.505	0.997
	35 – 45	-0.476	0.295	0.107
25 – 35	*45 - 55*	-2.326	0.298	0.000
	55 – 65	-4.232	0.400	0.000
	More than 65	-6.366	0.647	0.000
	Less than 25	0.478	0.482	0.322
	25 – 35	0.476	0.295	0.107
35 – 45	*45 - 55*	-1.850	0.257	0.000
	55 – 65	-3.756	0.371	0.000
	More than 65	-5.890	0.629	0.000
	Less than 25	2.328	0.484	0.000
	25 – 35	2.326	0.298	0.000
45 - 55	*35 – 45*	1.850	0.257	0.000
	55 – 65	-1.906	0.374	0.000
	More than 65	-4.040	0.631	0.000
	Less than 25	4.234	0.553	0.000
	25 – 35	4.232	0.400	0.000
55 – 65	*35 – 45*	3.756	0.371	0.000
	45 - 55	1.906	0.374	0.000
	More than 65	-2.134	0.685	0.002
	Less than 25	6.368	0.751	0.000
	25 – 35	6.366	0.647	0.000
More than 65	*35 – 45*	5.890	0.629	0.000
	45 - 55	4.040	0.631	0.000
	55 – 65	2.134	0.685	0.002

Table 23: Classification of significant levels for age categories

Age categories	n	Significant levels (mean of dependent variable) Level 1	Level 2	Level 3	Level 4
Less than 25	20	2.45			
25 – 35	73	2.45			
35 – 45	125	2.93			
45 – 55	117		4.78		
55 – 65	38			6.68	
More than 65	11				8.82

Figure 6 is illustrated for better understanding the prevalence of musculoskeletal discomfort with regards to age categories. The figure is the p-plot which is related to H_8.

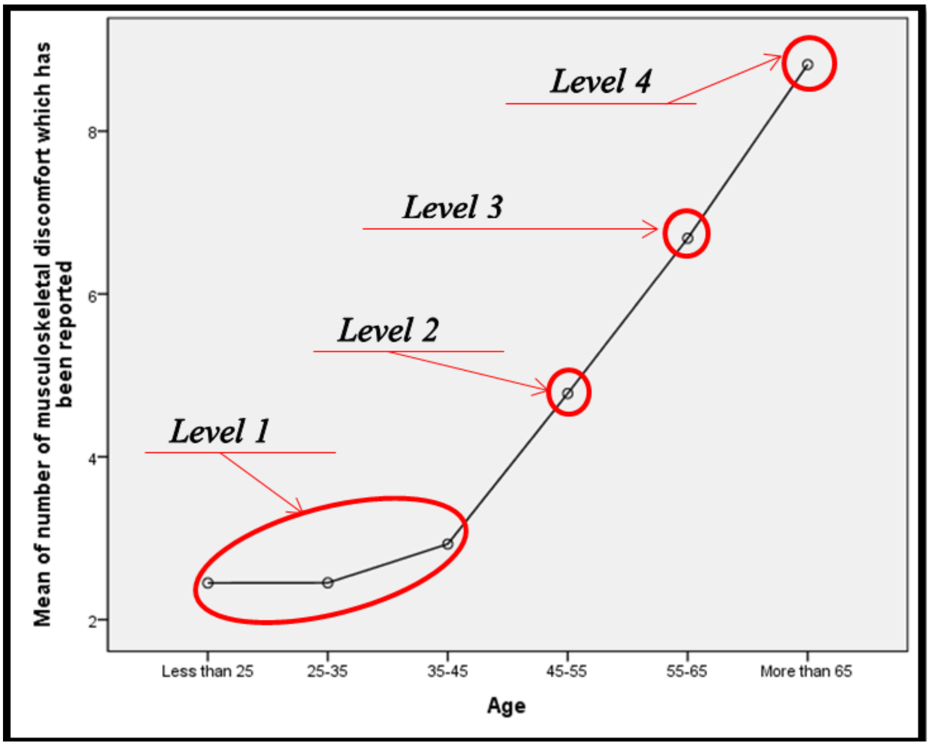

Figure 6: Prevalence of musculoskeletal discomfort by the increase of age

According to Figure 6, the prevalence of musculoskeletal discomfort is raised among drivers who were older than 45 years. And this increase is continued as the age goes higher; however, there is not any significant raising or falling for ages less than 45.

4.1.9 H_9 Results

Related to this hypothesis, cross tab of two independent variables is illustrated in Table 24.

Table 24: Cross tab for H_9

			Intensity of LBP			
			Mild	Severe	Very, very severe	Total
Days being prevented from work	0 day	Observed	13	79	62	154
		Expected	15.4	79.8	58.8	154
	1 – 7 days	Observed	3	19	10	32
		Expected	3.2	16.6	12.2	32
	8 – 30 days	Observed	4	11	1	16
		Expected	1.6	8.3	6.1	16
	More than 30 days	Observed	2	5	11	18
		Expected	1.8	9.3	6.9	18
	total	Observed	22	114	84	220
		Expected	22	114	84	220

According to Table 24, there are 3 expected values less than 5; therefore, fisher's exact test is determined the p-value of H_9. Outcomes of this test are as follows; the fisher exact value is 15.316; and, p-value is 0.012.

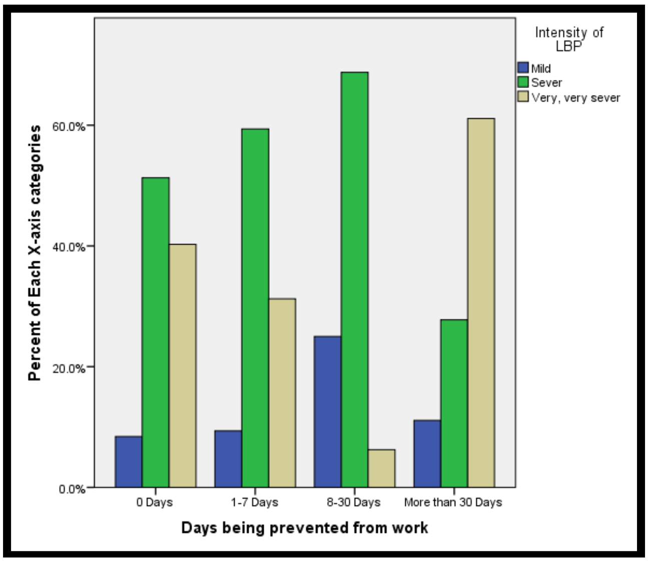

Figure 7: Bar chart of H_9 (percentage)

P-value is less than 0.05; thus, the null is rejected and H_9 is accepted. In order to illustrate the association of these two independent variables, Figure 7 is created.

As Figure 7 shows, those who prevented from doing their job for more than 30 days, mostly had experienced very intense LBP during the worst episodes.

4.1.10 H_{10} Results

Table 25 demonstrates a descriptive perspective of H_8. For the equality of variances, Table 26 demonstrates the Levene tests outcomes related to H_{10}.

Table 25: Descriptive table for H_{10}

Hurt the lower back in an accident	n	Mean	SD	Std. error	Min	Max
No	220	4.62	2.431	0.164	0	11
Yes	7	8.75	1.718	0.649	6	11
Total	227	4.74	2.505	0.166	0	11

Table 26: Levene test for H_{10}

Levene statistic	Df 1	Df 2	p-value
1.234	1	225	0.268

Because the p-value is greater than 0.05, the equality of variances assumption is acceptable for independent variable of H_{10}. Thus, ANOVA can be applied for this hypothesis. Table 27 illustrates the results of ANOVA test.

Table 27: Results of ANOVA tests for H_8

	Sum of square	Degrees of freedom	Mean square of error	F-value	p-value
Treatment	106.024	1	106.024	18.187	0.000
Error	1311.642	225	5.830		
total	1417.665	226			

According to Table 27, p-value is less than 0.05. Thus, the null is rejected and it is concluded that, there is a significant relation between drivers who experienced accident and the number of body parts they have experienced musculoskeletal discomfort during last 12 months. Multiple comparison techniques like Fisher LSD cannot be applied on this dependent variable because, the degree of freedom of independent variable is less than 2; therefore, the comparison between levels can be determined by constructing bar chart related to this hypothesis. Figure 8 shows the significant difference of two levels of dependent variable.

According to Figure 8, those drivers who hurt their back in an accident experienced more musculoskeletal discomforts in parts of their body.

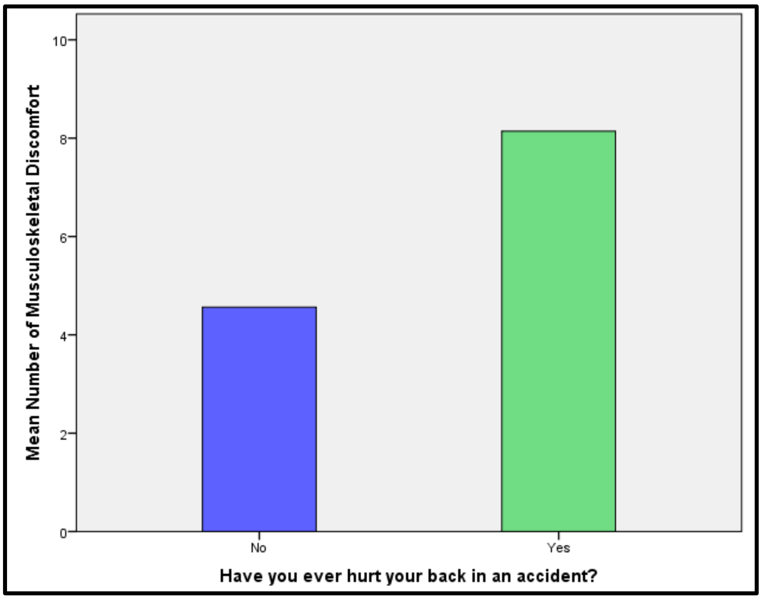

Figure 8: Bar chart of H_{10}

4.1.11 H_{11} Results

Table 28 demonstrates a descriptive perspective of H_{11}. Also Levene test outcomes for equality of variances are in Table 29.

Table 28: Descriptive table for H_{11}

Exposure time to vibration	n	Mean	SD	Std. error	Min	Max
Less than 56h	47	3.06	2.240	0.327	0	9
56 – 84h	120	3.33	2.349	0.214	0	11
84 – 112h	119	4.13	2.768	0.254	0	11
More than 112h	98	4.78	2.344	0.237	0	11
Total	384	3.92	2.543	0.130	0	11

Table 29: Leven test for H_{11}

Levene statistic	Df 1	Df 2	p-value
1.773	3	380	0.152

Because the p-value is greater than 0.05, the equality of variances assumption is acceptable for independent variable of H_{11}. Thus, ANOVA can be applied for this hypothesis. Table 30 illustrates the results of ANOVA test.

Table 30: Results of Welch and Brown-Forsythe tests for H_{11}

	Sum of square	Degrees of freedom	Mean square of error	F-value	p-value
Treatment	152.948	3	50.983	8.335	0.000
Error	2324.385	380	6.117		
total	2477.333	383			

According to Table 30, p-value is less than 0.05. Thus, the null is rejected and it is concluded that H_{11} is acceptable. For determining which levels of dependent variable in H_{11} are significant from others, Fisher Least Significant Difference (LSD) summaries of results are illustrated in Table 31 and 32. The same data is analyzed by Tuckey's method; but, the outcomes were slightly different from Fisher LSD method. Tables 33 and 34 illustrate the results of multiple comparisons for H_{11} using Tuckey's method. Subsequently, Figure 9 shows the p-plot of H_{11}. In this plot, blue color describes the classification based on Fisher LSD method and red color describes the classification based on Tuckey's method.

Table 31: Fisher LSD test for mean difference (H_{11})

Exposure (i)	*Exposure (j)*	*Mean difference (i-j)*	*Std. error*	*P-value*
	56 – 84h	-0.270	0.426	0.527
Less than 56h	*84 – 112h*	-1.071	0.426	0.012
	More than 112h	-1.712	0.439	0.000
	Less than 56h	0.270	0.426	0.527
56 – 84h	*84 – 112h*	-0.801	0.320	0.013
	More than 112h	-1.442	0.337	0.000
	Less than 56h	1.071	0.426	0.012
84 – 112h	*56 – 84h*	0.801	0.320	0.013
	More than 112h	-0.641	0.337	0.058
	Less than 56h	1.712	0.439	0.000
More than 112h	*56 – 84h*	1.442	0.337	0.000
	84 – 112h	0.641	0.337	0.058

Table 32: Classification of levels for exposure categories (Fisher LSD method)

Age categories	n	Significant levels (mean of dependent variable)		
		Level 1	Level 2	Level 3
Less than 56h	47	3.06		
56 – 84h	120	3.33		
84 – 112h	119		4.13	4.13
More than 112h	98			4.78

Table 33: Tuckey's test for mean difference (H11)

Exposure (i)	*Exposure (j)*	*Mean difference (i-j)*	*Std. error*	*P-value*
	56 – 84h	-0.270	0.426	0.921
Less than 56h	*84 – 112h*	-1.071	0.426	0.060
	More than 112h	-1.712	0.439	0.001
	Less than 56h	0.270	0.426	0.921
56 – 84h	*84 – 112h*	-0.801	0.320	0.061
	More than 112h	-1.442	0.337	0.000
	Less than 56h	1.071	0.426	0.060
84 – 112h	*56 – 84h*	0.801	0.320	0.061
	More than 112h	-0.641	0.337	0.230
	Less than 56h	1.712	0.439	0.001
More than 112h	*56 – 84h*	1.442	0.337	0.000
	84 – 112h	0.641	0.337	0.230

Table 34: Classification of levels for exposure categories (Tuckey's method)

Age categories	n	Significant levels (mean of dependent variable)		
		Level 1	Level 2	Level 3
Less than 56h	47	3.06		
56 – 84h	120	3.33	3.33	
84 – 112h	119		4.13	4.13
More than 112h	98			4.78

According to Figure 9, by the increase of hours of exposure to vibration, drivers report more musculoskeletal discomfort.

4.1.12 H_{12} Results

Table 35 shows the cross tab related to H_{12}. According to this table, all the expected values are greater than 0.05; therefore, the assumption of chi-square test of independent is applied for this hypothesis. Outcome of this test are as follows:

- Chi-square value = 57.949
- Degree of freedom = 6
- P-value = 0.000

P-value is smaller than 0.05. Thus, the null is rejected and H_{12} is accepted.

Figure 10 clarify the association of two independent variables of H_{12}.According to this figure, drivers who specified a higher score for their seat, experienced less neck discomfort during last 12 months.

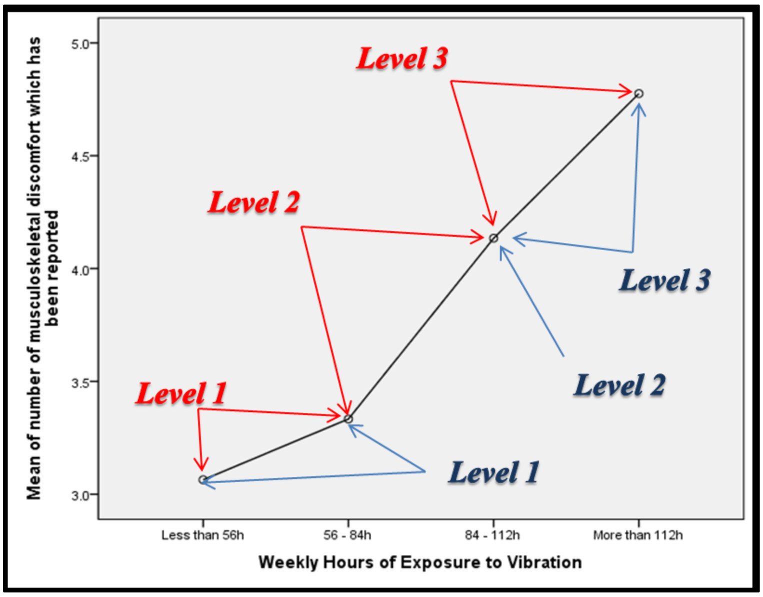

Figure 9: P-plot for H_{11}

Table 35: Cross tab for H_{12}

			Neck discomfort in last 12 months		Total
			No	*Yes*	
Seat score	***Dramatically uncomfortable***	*Observed*	1	14	15
		Expected	6.7	8.3	15
	Very uncomfortable	*Observed*	5	50	55
		Expected	24.6	30	55
	Uncomfortable	*Observed*	27	39	66
		Expected	29.6	36.4	66
	Normal	*Observed*	36	42	78
		Expected	34.9	43.1	78
	Comfortable	*Observed*	44	25	69
		Expected	30.9	38.1	69
	Very comfortable	*Observed*	46	38	84
		Expected	37.6	46.4	84
	Extremely comfortable	*Observed*	13	4	17
		Expected	7.6	9.4	17
	Total	*Observed*	172	212	384
		Expected	172	212	384

4.1.13 H_{13} Results

Cross tab related to H_{13} is illustrated in Table 36. There are two expected values less than 0.05. Therefore, instead of chi-square test, Fisher's exact test is used for H_{13}. Results of this test are as follows:

- Fisher's exact value = 39.187
- P-value = 0.000

P-value is less than 0.05. Thus, null is rejected and the statement of H_{13} is accepted.

In order to understand the association of seat comfort and shoulder discomfort, Figure 11 is illustrated. According to Figure 11, in the first two categories of seat score where it is not comfortable more prevalence of shoulder pain is observed. This result can be observed by the height of the blue column. In both categories, less than 20% of the drivers did not experienced any pain or discomfort in their shoulder area; and the rests reported discomfort at least in one of their shoulders for the period of 12 months.

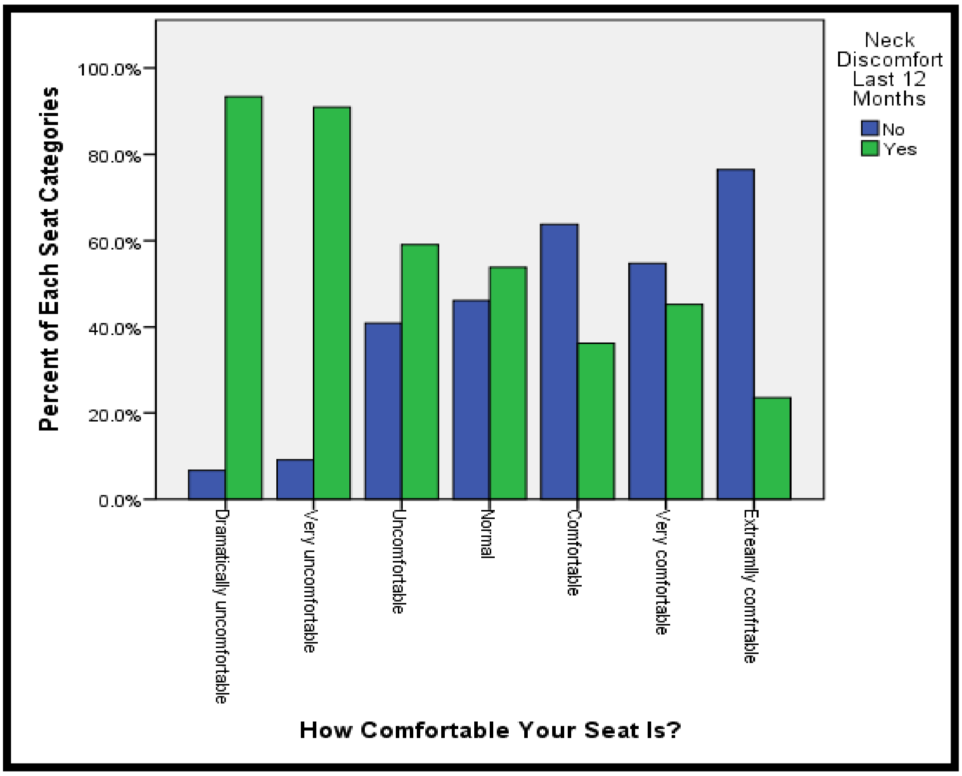

Figure 10: Bar chart of H_8

Table 36: Cross tab for H_{13}

			Neck discomfort in last 12 months			*Total*
			No	*Yes in one shoulder*	*Yes in both shoulders*	
Seat score	*Dramatically uncomfortable*	*Observed*	2	9	4	15
		Expected	5.4	6.1	3.5	15
	Very uncomfortable	*Observed*	9	22	24	55
		Expected	19.9	22.2	12.9	55
	Uncomfortable	*Observed*	27	19	20	66
		Expected	23.9	26.6	15.5	66
	Normal	*Observed*	29	36	13	78
		Expected	28.2	31.5	18.3	78
	Comfortable	*Observed*	33	19	17	69
		Expected	25	27.9	16.2	69
	Very comfortable	*Observed*	33	41	10	84
		Expected	30.4	33.9	19.7	84
	Extremely comfortable	*Observed*	6	9	2	17
		Expected	6.2	6.9	4	17
Total		*Observed*	139	155	90	384
		Expected	139	155	90	384

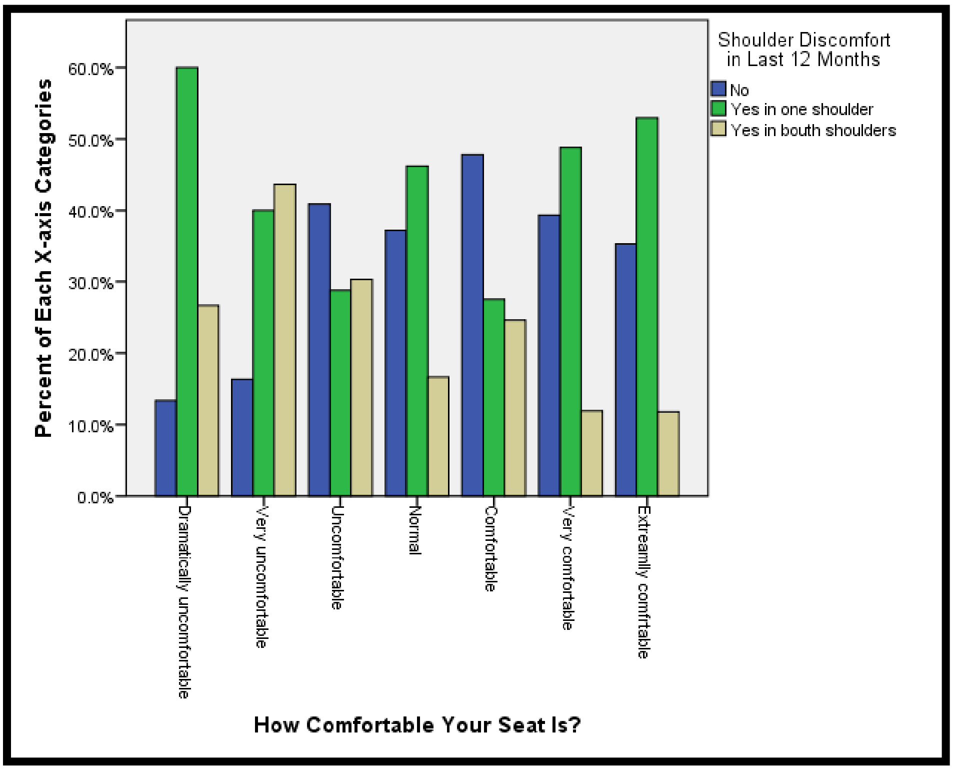

Figure 11: Bar chart of H_{13}

4.1.14 H_{14} Results

Table 37 illustrates the cross tab related to two independent variables of H_{14}.

Table 37: Cross tab for H_{14}

			Low back discomfort in last 12 months		*Total*
			No	*Yes*	
Adjustable lumber support	*Have*	*Observed*	24	172	196
		Expected	83.7	112.3	196
	Does not have	*Observed*	140	48	188
		Expected	80.3	107.7	188
	Total	*Observed*	164	220	384
		Expected	164	220	384

In Table 37, there are no expected values smaller than 5. Thus chi-square test assumption is ok for this hypothesis. Results of the test are as follows:

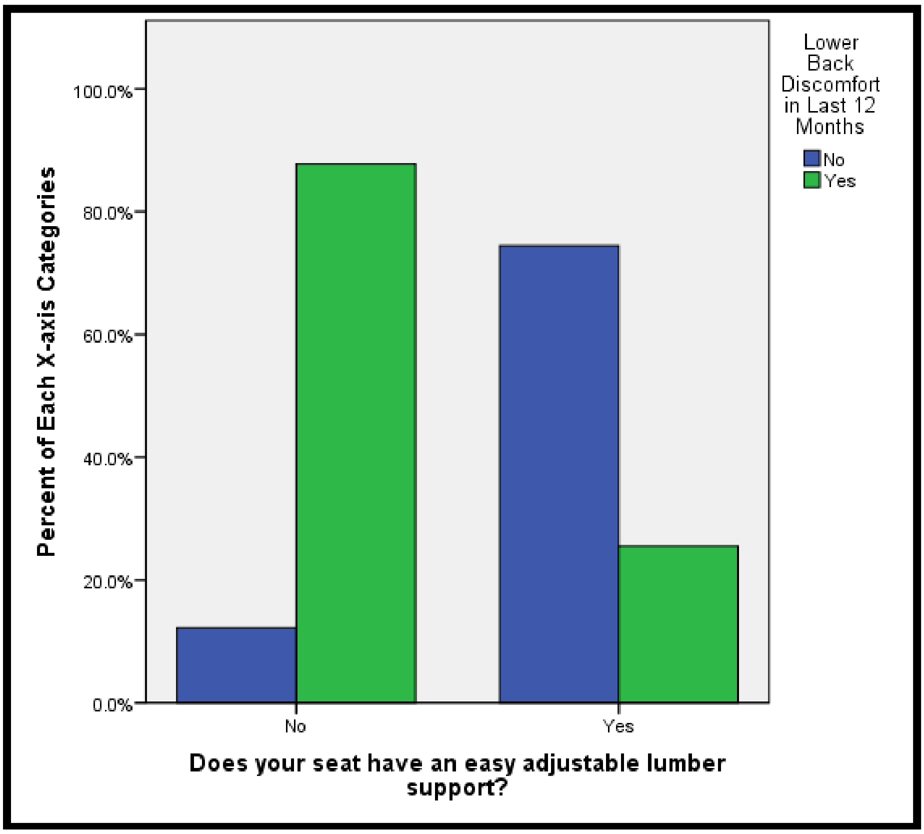

Figure 12: Bar chart of H_{14}

- Chi-square value = 151.839
- Degree of freedom = 1
- P-value = 0.000

P-value is less than 0.05. Therefore, null is rejected and H_{14} is accepted.

Figure 12 clarify that, drivers who does have an easy to adjusted lumber supports reported lower back discomfort less than those who does not have.

4.2 Regression Equations

In the following section, all the results are demonstrated; and consequently, equation models are proposed. The level 3 headings of 4.4 are according to Table 3.

4.2.1 Binary Logistic Regression Y_1

In order to run the binary logistic regression for Y_1, Table 38 shows the predictors and related Pearson's correlation values.

Table 38: Description of predictors related to Y_1

Predictor (address of the question)		*Pearson correlation*	*p-value*
(part 1 d)		-0.101	0.049
(part 2 e)		-0.103	0.043
Dramatically uncomfortable	(1)		
Very uncomfortable	(2)		
Uncomfortable	(3)		
Normal	(4)		
Comfortable	(5)		
Very comfortable	(6)		
Extremely comfortable	(7)		
(part 2 g)		-0.101	0.000
(part 2 h ii)		-0.200	0.047
(part 3 a)		0.128	0.012
(part 4 b)		0.243	0.000
(part 5 a)		-0.180	0.000
(part 5 c)		0.142	0.005

Table 38 clarifies 8 predictors for Y_1. (part 2 e) is a categorical predictor; therefore, it contains seven level; however, it must be mention that the SPSS software assigns only 6 codes for levels of this question; and therefor, the seventh level is the reference or base of the comparison of other levels. The Negelkerke's R-square of the model related to Y_1 predictors is 0.527.

Table 39 illustrates the classification table of the model. This table compares the outcomes which are predicted by model versus the observed.

Table 39: Classification table

		Predicted outcome for Y_1 question		percentage correct
		No	Yes	
Observed outcome for Y_1 question	No	5	16	23.8
	Yes	5	358	98.6
			Overall percentage	94.5

According to Table 39, 94.5% of the outcomes have been predicted correctly by the model. Table 40 shows a complete summary of the variables in the model.

Table 40: Results of binary logistic regression for Y_1

Predictors	*Coefficient*	*Standard error*	*Wald value*	*Df*	*P-value*	*Odds ratio*	*Label*
Part 1 d	0.115	.076	2.285	1	0.131	1.122	
Part 2 e			9.177	6	0.164		
Part 2 e (1)	16.008	8694.42	0.000	1	0.999	8955926.2	
Part 2 e (2)	16.518	3966.85	0.000	1	0.997	14915609.4	
Part 2 e (3)	-0.193	1.40	0.019	1	0.890	.824	
Part 2 e (4)	0.031	1.32	0.001	1	0.982	1.031	
Part 2 e (5)	-1.807	1.28	1.989	1	0.158	.164	
Part 2 e (6)	0.508	1.32	0.147	1	0.702	1.662	
Part 2 g	-19.336	3896.76	0.000	1	0.996	.000	
Part 2 h ii	-2.517	1.072	5.512	1	0.019	.081	X_1
Part 3 a	0.019	.012	2.393	1	0.022	1.019	X_2
Part 4 b	1.916	.907	4.460	1	0.035	6.795	X_3
Part 5 a	-0.207	.077	7.297	1	0.007	.813	X_4
Part 5 c	0.077	.028	7.513	1	0.006	1.080	X_5
Constant	195.263	3897.36	0.003	1	0.960	6.332E+084	

According to Wald test, X_1, X_2, X_3, X_4 and X_5 are the important predictors for $\hat{p}_1$; therefore, the equation related to this dependent variable is as follows:

$$\hat{p}_1 = \frac{e^{(-2.517X_1+0.019X_2+1.916X_3-0.207X_4+0.77X_5)}}{(1+e^{(-2.517X_1+0.019X_2+1.916X_3-0.207X_4+0.77X_5)})} \qquad (4.1)$$

Table 41 describes the numeric codes used for the variables in the model. For explaining the negative correlation of X_4, by increasing one unit of date of birth, likelihood of having a musculoskeletal discomfort in last 12 months would decrease with the odds ratio of 0.813. Thus, old drivers are more likely to have a musculoskeletal discomfort than younger ones.

4.2.2 Binary Logistic Regression Y_2

Table 42 demonstrates the Pearson's coefficients of the predictor variables related to Y_2. Relate to question of (part 2 e), it should be notice that the numbers in parentheses are the coded used in the SPSS software; and also, because this predictor is categorical the 7th level considered as the reference level and others would be compared to this level.

Table 41: Description of variables in equation 4.1

Variables	*Question*	*Answers*	*Numeric codes*
Y_1	*Did you have musculoskeletal trouble in any part of the body during last 12 months?*	*No* *Yes*	0 1
X_1	*Does your seat have an easy to adjusted lumber support?*	*No* *Yes*	0 1
X_2	*Hours of exposure to vibration*	*Numeric*	Numeric
X_3	*Did you ever have low back trouble?*	*No* *Yes*	0 1
X_4	*What is your date of birth*	*Numeric*	Numeric
X_5	*What is your weight in Kg*	*Numeric*	Numeric

Table 42: Description of predictors related to Y_2

Predictor (address of the question)		*Pearson correlation*	*p-value*
(part 1 d)		-0.389	0.000
(part 2 e)		-0.346	0.000
Dramatically uncomfortable	(1)		
Very uncomfortable	(2)		
Uncomfortable	(3)		
Normal	(4)		
Comfortable	(5)		
Very comfortable	(6)		
Extremely comfortable	(7)		
(part 2 f)		-0.247	0.000
(part 2 g)		-0.131	0.010
(part 2 h ii)		-0.124	0.015
(part 3 a)		0.380	0.000
(part 5 a)		-0.495	0.000

Table 43: Classification table

		Predicted outcome for Y_2 question		percentage correct
		No	Yes	
Observed outcome for Y_2 question	No	151	21	87.8
	Yes	16	196	92.5
			Overall percentage	90.4

The Negelkerke's R-square of the model related to Y_2 predictors is 0.711. Moreover, Table 43 compares the predictions of the model related to Y_2 versus the observations. According to this table 90.4 percent of the predictions are correct.

Table 44: Results of binary logistic regression for Y_2

Predictors	*Coefficient (β_i)*	*Standard error*	*Wald value*	*Df*	*P-value*	*Odds ratio*	*Label*
Part 1 d	-0.081	0.02	11.52	1	0.001	0.922	X_1
Part 2 e			36.81	6	0.000		
Part 2 e (1)	5.554	1.51	13.47	1	0.000	258.183	X_2
Part 2 e (2)	4.848	1.11	19.10	1	0.000	127.526	X_3
Part 2 e (3)	3.097	0.95	10.60	1	0.001	22.121	X_4
Part 2 e (4)	2.366	0.90	6.98	1	0.008	10.654	X_5
Part 2 e (5)	0.888	0.90	0.98	1	0.321	2.430	X_6
Part 2 e (6)	1.210	0.86	1.98	1	0.159	3.353	X_7
Part 2 f	-2.138	0.83	6.65	1	0.010	0.118	X_8
Part 2 g	-0.781	0.49	2.50	1	0.114	0.458	
Part 2 h ii	-0.185	0.36	0.27	1	0.605	0.831	
Part 3 a	0.063	0.01	56.08	1	0.000	1.065	X_9
Part 5 a	-0.152	0.02	39.31	1	0.000	0.859	X_{10}
Constant	457.868	54.09	71.66	1	0.000		β_0

$$\hat{p}_2 = \frac{e^{(457.69-0.08X_1+5.55X_2+4.85X_3+3.10X_4+2.37X_5 0.89X_6+1.21X_7-2.14X_8+0.06X_9-0.15X_{10})}}{1+e^{(457.69-0.08X_1+5.55X_2+4.85X_3+3.10X_4+2.37X_5 0.89X_6+1.21X_7-2.14X_8+0.06X_9-0.15X_{10})}} \qquad (4.2)$$

Table 44 illustrates the complete summary of the Logistic regression outcome related to Y_2.Important predictors for equation 4.2 are selected from Table 44; thereafter, the equation 4.2 is related to dependent variable of Y_2.

Table 45: Description of variables in equation 4.2

Variables	*Question*	*Answers*	*Numeric codes*
Y_3	*Did you have musculoskeletal trouble in neck area during last 12 months?*	*No* *Yes*	0 1
X_1	*Since which date did you start this occupation?*	*Numeric*	*Numeric*
X_2-X_5	*In scale of 1-7, how do you rate your seat to be comfortable?*	*Categorical*	Scale of seven
X_6	*Does your seat have an easy to adjusted suspension?*	*No* *Yes*	0 1

4.2.3 Multinomial Logistic Regression Y_3

As it discussed in chapter 3 for Y_3 three equations are needed. The base of the comparison for these equations is the reports that the drivers experienced shoulder pain in both side. Thus, Table 46 demonstrates the variables which have correlation with dependent variable of Y_3. Tables 47, 48 and 49 illustrate the outcomes of the predicted variables with their properties in the relevant equations. The Negelkerke's

R-square of the model related to Y_3 predictors is 0.755. Equations 4.3, 4.4 and 4.5 are related to Tables 47, 48 and 49 respectively.

Table 46: Description of predictors related to Y_3

Predictor (address of the question)		*Pearson correlation*	*p-value*
(part 2 e)		-0.184	0.000
Dramatically uncomfortable	(1)		
Very uncomfortable	(2)		
Uncomfortable	(3)		
Normal	(4)		
Comfortable	(5)		
Very comfortable	(6)		
Extremely comfortable	(7)		
(part 2 f)		-0.210	0.000
(part 2 g)		-0.518	0.000
(part 2 h i)		-0.127	0.000
(part 3 a)		0.316	0.000
(part 5 a)		-0.170	0.000

Table 47: Y_3 results for the comparison of "No" with "In both sides"

Predictors	***Coefficient (β_i)***	***Standard error***	***Wald value***	***Df***	***P-value***	***Odds ratio***	***Label***
Answering "No" to the question of Y_3							
Part 2 e (1)	3.503	1.60	4.79	1	0.029	33.207	X_1
Part 2 e (2)	2.337	1.22	3.67	1	0.055	10.347	
Part 2 e (3)	2.371	1.16	4.21	1	0.040	10.709	X_2
Part 2 e (4)	1.638	1.08	2.29	1	0.130	5.145	
Part 2 e (5)	1.494	1.06	1.99	1	0.159	4.455	
Part 2 e (6)	1.062	1.03	1.06	1	0.302	2.891	
Part 2 f	-3.763	0.80	22.04	1	0.000	0.023	X_3
Part 2 g	-6.294	0.92	46.35	1	0.000	0.002	X_4
Part 2 h i	-1.496	0.69	4.77	1	0.029	0.224	X_5
Part 3 a	-0.020	0.01	4.72	1	0.030	0.980	X_6
Part 5 a	0.113	0.02	25.83	1	0.000	1.120	X_7
Constant	-219.292	43.97	24.88	1	0.000		β_0

Table 48: Y_3 results for the comparison of "In left side" with "In both sides"

Predictors	***Coefficient (β_i)***	***Standard error***	***Wald value***	***Df***	***P-value***	***Odds ratio***	***Label***
Answering "yes in left side" to the question of Y_3							
Part 2 e (1)	3.512	1.65	4.52	1	0.034	33.511	X_1
Part 2 e (2)	2.035	1.27	2.55	1	0.110	7.654	
Part 2 e (3)	0.631	1.26	0.25	1	0.616	1.880	
Part 2 e (4)	0.717	1.17	0.38	1	0.540	2.049	
Part 2 e (5)	0.263	1.17	0.05	1	0.822	1.301	
Part 2 e (6)	-0.306	1.13	0.07	1	0.787	0.737	
Part 2 f	-2.289	0.74	9.49	1	0.002	0.101	X_2
Part 2 g	-4.530	0.80	32.39	1	0.000	0.011	X_3
Part 2 h i	-1.023	0.75	1.86	1	0.172	0.359	
Part 3 a	-0.063	0.01	36.40	1	0.000	0.939	X_4
Part 5 a	-0.066	0.02	7.86	1	0.005	0.937	X_5
Constant	135.173	46.32	8.52	1	0.004		β_0

Table 49: Y_3 results for the comparison of "In right side" with "In both sides"

Predictors	*Coefficient (β_i)*	*Standard error*	*Wald value*	*Df*	*P-value*	*Odds ratio*	*Label*
Answering "yes in right side" to the question of Y_3							
Part 2 e (1)	2.456	1.62	2.30	1	0.129	11.656	
Part 2 e (2)	0.965	1.30	0.55	1	0.459	2.624	
Part 2 e (3)	0.951	1.28	0.56	1	0.456	2.589	
Part 2 e (4)	0.386	1.18	0.11	1	0.745	1.471	
Part 2 e (5)	-0.837	1.21	0.48	1	0.487	0.433	
Part 2 e (6)	0.417	1.15	0.13	1	0.717	1.518	
Part 2 f	-2.862	0.86	10.98	1	0.001	0.057	X_1
Part 2 g	-5.554	1.06	27.37	1	0.000	0.004	X_2
Part 2 h i	17.894	0.00	0.16	1	1.000	0.941	
Part 3 a	0.060	0.01	22.83	1	0.000	1.061	X_3
Part 5 a	0.085	0.02	12.02	1	0.001	1.088	X_4
Constant	-189.746	48.44	15.35	1	0.000		β_0

$$\hat{p}_{3.1} = \frac{e^{(-219.292+3.503X_1+2.371X_2-3.763X_3-6.294X_4-1.496X_5-0.020X_6+0.113X_7)}}{1+e^{(-219.292+3.503X_1+2.371X_2-3.763X_3-6.294X_4-1.496X_5-0.020X_6+0.113X_7)}} \quad (4.3)$$

$$\hat{p}_{3.2} = \frac{e^{(135.173+3.512X_1-2.289X_2-4.530X_3-0.063X_4-0.066X_5)}}{1+e^{(135.173+3.512X_1-2.289X_2-4.530X_3-0.063X_4-0.066X_5)}} \quad (4.4)$$

$$\hat{p}_{3.3} = \frac{e^{(-189.746-2.289X_1-5.554X_2+0.060X_3+0.085X_4)}}{1+e^{(-189.746-2.289X_1-5.554X_2+0.060X_3+0.085X_4)}} \quad (4.5)$$

Equation 4.3 determines the probability of the answer of Y_3 is "No" rather than "Yes in both shoulders". Followed by equation 4.3, equation 4.4 estimates the probability of the answer of Y_3 is "Yes in left shoulder" rather than "Yes in both shoulders"; and subsequently, equation 4.5 estimates the probability of the answer of Y_3 is "Yes in right shoulder" rather than "Yes in both shoulders". For better understanding of the variables, Table 50 provides the properties of the significant variables in equations 4.3, 4.4 and 4.5.

4.2.4 Multinomial Logistic Regression Y_4

The same as multinomial logistic regression for shoulders, Tables 51 to 55 is illustrated to determine the variables of the equations related to elbows answers (Y_4).

Table 50: Description of variables in equations 4.3, 4.4 and 4.5

Variables	*Question*	*Answers*	*Numeric codes*
Y_3	*Did you have musculoskeletal trouble in shoulders area during last 12 months?*	*No*	0
		Yes in left side	1
		Yes in right side	2
		Yes in both sides	3
X_4 *(table 47)*	*Is your seat easy to adjust*	*No*	0
		Yes	1
X_5 *(table 47)*	*Does your seat have an armrest?*	*No*	0
		Yes	1

It should also be mentioned that the Negelkerke's R-square of this model is 0.495.

Table 51: Description of predictors related to Y_4

Predictor (address of the question)		*Pearson correlation*	*p-value*
(part 2 e)		-0.102	0.047
Dramatically uncomfortable	(1)		
Very uncomfortable	(2)		
Uncomfortable	(3)		
Normal	(4)		
Comfortable	(5)		
Very comfortable	(6)		
Extremely comfortable	(7)		
(part 1 d)		-0.334	0.000
(part 2 h ii)		-0.137	0.007
(part 5 a)		-0.456	0.000

There are no other undefined significant variables in tables 4.6, 4.7 and 4.8. Questions related to these significant variables are identified in previous description tables. Equations 4.6, 4.7 and 4.8 are the outcomes of the significant parameters in Tables 52, 53 and 54.

Table 52: Y_4 results for the comparison of "No" with "In both sides"

Predictors	***Coefficient (β_i)***	***Standard error***	***Wald value***	***Df***	***P-value***	***Odds ratio***	***Label***
Answering "No" to the question of Y_4							
Part 2 e (1)	16.771	5603.715	.000	1	0.998	1.92+E07	
Part 2 e (2)	-0.791	1.444	.300	1	0.584	0.454	
Part 2 e (3)	0.289	1.448	.040	1	0.842	1.335	
Part 2 e (4)	0.848	1.428	.353	1	0.552	2.336	
Part 2 e (5)	0.147	1.399	.011	1	0.916	1.158	
Part 2 e (6)	1.387	1.369	1.025	1	0.311	4.001	
Part 1 d	0.043	0.024	3.312	1	0.069	1.044	
Part 2 h ii	-0.701	0.619	1.282	1	0.258	0.496	
Part 5 a	0.236	0.037	40.424	1	0.000	1.267	X_1
Constant	-547.954	87.732	39.009	1	0.000		β_0

Table 53: Y_4 results for the comparison of "In left side" with "In both sides"

Predictors	*Coefficient (β_i)*	*Standard error*	*Wald value*	*Df*	*P-value*	*Odds ratio*	*Label*
Answering "Yes in left side" to the question of Y_4							
Part 2 e (1)	-2.632	0.000	0	1	0.999	0.072	
Part 2 e (2)	-20.880	9087.578	.000	1	0.998	0.000	
Part 2 e (3)	-1.086	1.841	.348	1	0.555	0.338	
Part 2 e (4)	-0.058	1.760	.001	1	0.974	0.944	
Part 2 e (5)	-1.149	1.793	.410	1	0.522	0.317	
Part 2 e (6)	0.281	1.709	.027	1	0.869	1.325	
Part 1 d	0.034	0.038	.793	1	0.373	1.035	
Part 2 h ii	0.497	0.882	.318	1	0.573	1.644	
Part 5 a	0.150	0.046	10.473	1	0.001	1.162	X_1
Constant	-362.807	108.188	11.246	1	0.001		β_0

Table 54: Y_4 results for the comparison of "In right side" with "In both sides"

Predictors	*Coefficient (β_i)*	*Standard error*	*Wald value*	*Df*	*P-value*	*Odds ratio*	*Label*
Answering "Yes in right side" to the question of Y_4							
Part 2 e (1)	34.689	9564.256	.000	1	0.997	1.162+E 15	
Part 2 e (2)	17.980	7750.702	.000	1	0.998	6.435+E 07	
Part 2 e (3)	17.206	7750.702	.000	1	0.998	2.967+E 07	
Part 2 e (4)	17.805	7750.702	.000	1	0.998	5.404+E 07	
Part 2 e (5)	16.362	7750.702	.000	1	0.998	1.275+E 07	
Part 2 e (6)	17.260	7750.702	.000	1	0.998	3.132+E 07	
Part 1 d	-0.233	0.103	5.068	1	0.024	0.793	X_1
Part 2 h ii	0.232	0.936	.061	1	0.804	1.261	
Part 5 a	0.386	0.112	11.898	1	0.001	1.471	X_2
Constant	-312.616	7751.385	.002	1	0.968		

$$\hat{p}_{4.1} = \frac{e^{(-547.954+0.236X_1)}}{1+e^{(-547.954+0.236X_1)}} \tag{4.6}$$

$$\hat{p}_{4.2} = \frac{e^{(-362.807+0.15X_1)}}{1+e^{(-362.807+0.15X_1)}} \tag{4.7}$$

$$\hat{p}_{4.3} = \frac{e^{(-0.233X_1+0.386X_2)}}{1+e^{(-0.233X_1+0.386X_2)}} \tag{4.8}$$

Related to variables in the equations Y4 is the dependent variable related to this question: *Did you have musculoskeletal trouble in elbows during last 12 months?* And the numeric codes for the answers are the same as multinomial regression for shoulder area.

Table 55: Description of variables in equations 4.3, 4.4 and 4.5

Variables	***Question***	***Answers***	***Numeric codes***
Y_4	*Did you have musculoskeletal trouble in elbows during last 12 months?*	*No*	0
		Yes in left side	1
		Yes in right side	2
		Yes in both sides	3
X_4 *(table 47)*	*Is your seat easy to adjust*	*No*	0
		Yes	1
X_5 *(table 47)*	*Does your seat have an armrest?*	*No*	0
		Yes	1

4.2.5 Multinomial Logistic Regression Y_5

For the discomfort of wrists, the following results are demonstrated by multinomial logistic regression analyze. Table 57, 58 and 59 are respectively demonstrates the variables in the equations 4.9, 4.10 and 4.11.

Table 56: Description of predictors related to Y_5

Predictor (address of the question)	*Pearson correlation*	*p-value*
(part 1 d)	-0.438	0.000
(part 2 h i)	-0.123	0.016
(part 3 a)	0.131	0.010
(part 5 a)	-0.554	0.000

Table 57: Y_5 results for the comparison of “No” with “In both sides”

Predictors	***Coefficient (β_i)***	***Standard error***	***Wald value***	***Df***	***P-value***	***Odds ratio***	***Label***
Answering “No” to the question of Y_5							
(part 1 d)	0.091	0.026	12.16	1	0.000	1.095	X_1
(part 2 h i)	-16.912	1222.032	0.00	1	0.989	0.000	
(part 3 a)	-0.021	0.009	6.04	1	0.014	0.979	X_2
(part 5 a)	0.227	0.033	47.48	1	0.000	1.255	X_3
Constant	-606.851	1224.821	0.25	1	0.620		

Table 58: Y_5 results for the comparison of “In left side” with “In both sides”

Predictors	***Coefficient (β_i)***	***Standard error***	***Wald value***	***Df***	***P-value***	***Odds ratio***	***Label***
Answering “Yes in left side” to the question of Y_5							
(part 1 d)	0.075	0.051	2.19	1	0.139	1.078	
(part 2 h i)	-18.747	1222.032	0.00	1	0.988	0.000	
(part 3 a)	-0.017	0.015	1.30	1	0.254	0.983	
(part 5 a)	0.192	0.053	12.88	1	0.000	1.212	X_1
Constant	-509.325	1227.713	0.17	1	0.678		

Table 59: Y_5 results for the comparison of "In right side" with "In both sides"

Predictors	*Coefficient (β_i)*	*Standard error*	*Wald value*	*Df*	*P-value*	*Odds ratio*	*Label*
Answering "Yes in right side" to the question of Y_5							
(part 1 d)	0.071	0.027	7.13	1	0.008	1.074	X_1
(part 2 h i)	-18.747	1222.032	0.00	1	0.988	0.000	
(part 3 a)	-0.006	0.010	0.39	1	0.534	0.994	
(part 5 a)	0.100	0.032	9.86	1	0.002	1.105	X_2
Constant	-337.612	82.654	16.68	1	0.000		β_0

The Negelkerke's R-square related to this regression is 0.50. The question related to variable Y_5 is as follow: Did you have musculoskeletal trouble in wrists during last 12 months? It contains three answers as no, yes in left side, yes in right side and yes in both sides. These answers have numeric codes of 0, 1, 2 and 3 respectively. The rest of the variables are already explained in previous equations. By using Tables 57, 58 and 59 equations 4.9, 410 and 4.11 are written. Related to equation 4.10, age of the drivers is the only significant predictor of wrist discomfort.

$$\hat{p}_{5.1} = \frac{e^{(0.091X_1 - 0.021X_1 + 0.227X_1)}}{1+e^{(0.091X_1 - 0.021X_1 + 0.227X_1)}} \qquad (4.9)$$

$$\hat{p}_{5.2} = \frac{e^{(0.192X_1)}}{1+e^{(0.192X_1)}} \qquad (4.10)$$

$$\hat{p}_{5.3} = \frac{e^{(-337.612 - 0.071X_1 + 0.1X_2)}}{1+e^{(-337.612 - 0.071X_1 + 0.1X_2)}} \qquad (4.11)$$

4.2.6 Binary Logistic Regression Y_6

Since the same method are used for the rest of the regressions until Y_{20} (Binary logistic regression) the following description is demonstrated for all the tables related to $Y_6 - Y_{20}$.

First, Tables 60, 63, 66, 70, 73, 76, 79, 82, 85, 88, 91, 94 and 99 are the results of Pearson correlation for those predictors which are significantly correlated with the dependent variables.

Second, Tables 61, 64, 66, 68, 71, 74, 77, 80, 83, 86, 89, 92, 95, 97 and 100 are the results of difference of observed data versus the data which are predicted by the regression equations. Overall percentage in each table clarifies how accurately the equation predicts the discomfort in that specific area.

Third, Tables 62, 65, 67, 69, 72, 75, 78, 81, 84, 87, 90, 93, 96, 98 and 101are the variables in the equations related to each part of the body.

Last but not least, equations 4.11, 4.12, 4.13, 4.14, 4.15, 4.16, 4.17, 4.18, 4.19 and 4.20 are to estimates the probability of occurrence of discomfort for related part of the body. The Negelkerke's R-square for this binary logistic regression is 0.591. The question related to Y_6 is as follow: Did you have musculoskeletal trouble in upper back area during last 12 months? The code 0 stands for answering *"No"* and the code one is "*Yes*".

Table 60: Description of predictors related to Y_6

Predictor (address of the question)		*Pearson correlation*	*p-value*
(part 2 e)		-0.408	0.000
Dramatically uncomfortable	(1)		
Very uncomfortable	(2)		
Uncomfortable	(3)		
Normal	(4)		
Comfortable	(5)		
Very comfortable	(6)		
Extremely comfortable	(7)		
(part 2 g)		-0.195	0.000
(part 2 h ii)		-0.593	0.000
(part 4 b)		0.408	0.000
(part 5 a)		-0.182	0.000

Table 61: Classification table

		Predicted outcome for Y_5 question		percentage correct
		No	Yes	
Observed outcome for Y_5 question	No	230	26	89.8
	Yes	27	101	78.9
			Overall percentage	86.2

Table 62: Results of binary logistic regression for Y_6

Predictors	*Coefficient*	*Standard error*	*Wald value*	*Df*	*P-value*	*Odds ratio*	*Label*
Part 2 e			22.17	6	0.001		
Part 2 e (1)	1.680	1.334	1.59	1	0.208	5.364	X_1
Part 2 e (2)	2.051	1.212	2.86	1	0.091	7.772	X_2
Part 2 e (3)	1.906	1.190	2.57	1	0.109	6.727	X_3
Part 2 e (4)	0.680	1.182	0.33	1	0.565	1.974	X_4
Part 2 e (5)	0.400	1.200	0.11	1	0.739	1.491	X_5
Part 2 e (6)	0.155	1.212	0.02	1	0.898	1.167	X_6
Part 2 g	-1.231	0.467	6.96	1	0.008	0.292	X_7
Part 2 h ii	-2.873	0.469	37.50	1	0.000	0.057	X_8
Part 4 b	1.007	0.436	5.35	1	0.021	2.737	X_9
Part 5 a	-0.059	0.015	15.66	1	0.000	0.942	X_{10}
Constant	116.602	29.795	15.32	1	0.000		β_0

With regard to Table 62 the formula of logistic regression related to this part is as follow:

$$\hat{p_6} = \frac{e^{(116.60-1.68X_1-2.05X_2+1.91X_3-0.068X_4+0.4X_5-0.15X_6-1.23X_7-2.87X_8+1.01X_9-0.06X_{10})}}{1+e^{(116.60-1.68X_1-2.05X_2+1.91X_3-0.068X_4+0.4X_5-0.15X_6-1.23X_7-2.87X_8+1.01X_9-0.06X_{10})}} \quad (4.11)$$

4.2.7 Binary Logistic Regression Y_7

Table 63: Description of predictors related to Y_7

Predictor (address of the question)	*Pearson correlation*	*p-value*
(part 1 d)	-0.145	0.005
(part 2 h ii)	-0.629	0.000
(part 3 e ii)	-0.121	0.018
(part 4 b)	0.963	0.000
(part 5 a)	-0.144	0.005
(part 5 c)	0.271	0.000

The Negelkerke's R-square for this binary logistic regression is 0.724.

Table 64: Classification table

		Predicted outcome for Y_6 question		percentage correct
		No	Yes	
Observed outcome for Y_6 question	No	159	5	97.0
	Yes	1	219	99.5
			Overall percentage	98.4

Table 65: Results of binary logistic regression for Y_7

Predictors	*Coefficient*	*Standard error*	*Wald value*	*Df*	*P-value*	*Odds ratio*	*Label*
part 1 d	-0.074	0.056	1.75	1	0.186	0.929	
part 2 h ii	-19.765	1952.361	0.00	1	0.992	0.000	
part 3 e ii	0.042	0.059	0.50	1	0.481	1.043	
part 4 b	39.924	3094.716	0.00	1	0.990	2.180E+17	
part 5 a	-0.008	0.043	0.03	1	0.859	0.992	
part 5 c	0.101	0.038	7.11	1	0.008	1.106	X_1
Constant	134.991	2403.155	0.00	1	0.955		

$$\hat{p}_7 = \frac{e^{(0.101X_1)}}{1+e^{(0.101X_1)}} \qquad (4.12)$$

Related question to Part 4 b is “Have you *ever* had any low back trouble?” Since the logic of this question is highly related to the dependent variable (those who have LBP during last 12 month will definitely answer this question “Yes”) we added another regression without considering part 4 b as a predictor and the results are as below:

Table 66: Classification table

		Predicted outcome for Y_7 question		percentage correct
		No	Yes	
Observed outcome for Y_7 question	No	140	24	85.4
	Yes	24	196	89.1
			Overall percentage	87.5

The Negelkerke’s R-square for this binary logistic regression is 0.639. It is obvious that by neglecting a significant predictor from the regression, the Negelkerke’s R-square would be reduced.

Table 67: Results of binary logistic regression for Y_7 without Part4b

Predictors	*Coefficient*	*Standard error*	*Wald value*	*Df*	*P-value*	*Odds ratio*	*Label*
part 1 d	-0.034	0.021	2.53	1	0.112	0.967	
part 2 h ii	-4.279	0.416	105.85	1	0.000	0.014	X_1
part 3 e ii	-0.005	0.020	0.06	1	0.813	0.995	
part 5 a	-0.039	0.019	4.14	1	0.042	0.962	X_2
part 5 c	0.096	0.014	49.63	1	0.000	1.101	X_3
Constant	138.771	35.661	15.14	1	0.000		β_0

$$\hat{p}_7{}' = \frac{e^{(138.771-4.279X_1-0.039X_2+0.096X_3)}}{1+e^{(138.771-4.279X_1-0.039X_2+0.096X_3)}} \qquad (4.13)$$

4.2.8 Binary Logistic Regression Y_8

The only question that has correlation with the discomfort of buttocks area is part 1 d. This question has a Pearson correlation of 0.112 and the p-value of 0.028.

Table 68: Classification table

		Predicted outcome for Y_8 question		percentage correct
		No	Yes	
Observed outcome for Y_8 question	No	260	0	100
	Yes	124	0	0
			Overall percentage	67.7

Table 69: Results of binary logistic regression for Y_8

Predictors	*Coefficient*	*Standard error*	*Wald value*	*Df*	*P-value*	*Odds ratio*	*Label*
Part 1 d	0.025	0.012	4.774	1	0.029	1.026	X_1
Constant	-51.247	23.121	4.913	1	0.027		β_0

The Negelkerke's R-square for this binary logistic regression is 0.611.

$$\hat{p}_8 = \frac{e^{(-51.247+0.025X_1)}}{1+e^{(-51.247+0.025X_1)}} \qquad (4.14)$$

4.2.9 Binary Logistic Regression Y_9

Table 70: Description of predictors related to Y_9

Predictor (address of the question)	*Pearson correlation*	*p-value*
(part 1 d)	-0.397	0.000
(part 2 d)	-0.117	0.022
(part 3 a)	0.306	0.000
(part 4 b)	0.121	0.018
(part 5 a)	-0.575	0.000
(part 5 c)	0.213	0.000
(part 5 d)	0.115	0.024

Table 71: Classification table

		Predicted outcome for Y_9 question		percentage correct
		No	Yes	
Observed outcome for Y_9 question	No	190	22	89.6
	Yes	17	155	90.1
			Overall percentage	89.8

Table 72: Results of binary logistic regression for Y_9

Predictors	***Coefficient***	***Standard error***	***Wald value***	***Df***	***P-value***	***Odds ratio***	***Label***
Part 1 d	-0.007	0.021	0.095	1	0.758	0.993	
Part 2 d	0.020	0.012	2.859	1	0.091	0.980	
Part 3 a	0.036	0.006	38.112	1	0.000	1.037	X_1
Part 4 b	-0.129	0.310	0.173	1	0.677	0.879	
Part 5 a	-0.192	0.025	57.385	1	0.000	0.825	X_2
Part 5 c	0.057	0.013	19.833	1	0.000	1.058	X_3
Part 5 d	1.471	1.291	1.298	1	0.255	4.355	
Constant	421.887	49.653	72.193	1	0.000	1.67 E+183	β_0

The Negelkerke's R-square for this binary logistic regression is 0.567.

$$\hat{p_9} = \frac{e^{(421.887+0.036X_1-0.192X_2+0.057X_3)}}{1+e^{(421.887+0.036X_1-0.192X_2+0.057X_3)}} \quad (4.15)$$

4.2.10 Binary Logistic Regression Y_{10}

Table 73: Description of predictors related to Y_{10}

Predictor (address of the question)	*Pearson correlation*	*p-value*
(part 3 a)	0.136	0.008
(part 5 a)	-0.188	0.046
(part 5 e)	-0.106	0.038

Table 74: Classification table

		Predicted outcome for Y_{10} question		percentage correct
		No	Yes	
Observed outcome for Y_{10} question	No	256	1	99.7
	Yes	98	0	0
			Overall percentage	74.2

Table 75: Results of binary logistic regression for Y_{10}

Predictors	***Coefficient***	***Standard error***	***Wald value***	***Df***	***P-value***	***Odds ratio***	***Label***
Part 3 a	0.012	0.004	6.898	1	0.009	1.012	X_1
Part 5 a	-0.017	0.011	2.417	1	0.120	0.983	
Part 5 c	-0.825	0.404	4.183	1	0.041	0.438	X_2
Constant	32.030	21.332	2.254	1	0.133	8.136E+13	

The Negelkerke's R-square for this binary logistic regression is 0.056.

The significant predictors of ankles are the hours that they were exposed to WBV in week and their weight; however, the coefficient related to the weight of the drivers is negative and it means that by increase of weight the probability of reporting musculoskeletal discomfort would decrease. Such an odd outcome could be the result of low prevalence of musculoskeletal discomfort among drivers.

According to Figure 1 prevalence of ankles is only 26%. This would consequently causes a lower Negelkerke's R-square as well.

$$\hat{p}_{10} = \frac{e^{(0.012X_1 - 0.825X_2)}}{1+e^{(0.012X_1 - 0.825X_2)}} \quad (4.15)$$

4.2.11 Binary Logistic Regression Y_{11}

Table 76: Description of predictors related to Y_{11}

Predictor (address of the question)		*Pearson correlation*	*p-value*
(part 1 d)		-0.215	0.000
(part 2 e)		-0.103	0.044
Dramatically uncomfortable	(1)		
Very uncomfortable	(2)		
Uncomfortable	(3)		
Normal	(4)		
Comfortable	(5)		
Very comfortable	(6)		
Extremely comfortable	(7)		
(part 2 h ii)		-0.259	0.000
(Part 3 a)		0.168	0.001
(part 4 b)		0.339	0.000
(part 5 a)		-0.257	0.000
(Part 5 c)		0.144	0.005

Table 77. Classification table

		Predicted outcome for Y_{11} question		percentage correct
		No	Yes	
Observed outcome for Y_{11} question	No	20	25	44.4
	Yes	10	329	97.1
			Overall percentage	90.9

Table 78: Results of binary logistic regression for Y_{11}

Predictors	***Coefficient***	***Standard error***	***Wald value***	***Df***	***P-value***	***Odds ratio***	***Label***
Part 1 d	-0.005	0.04	0.018	1	0.893	0.995	
Part 2 e			8.837	6	0.183		
Part 2 e (1)	0.850	1.46	0.339	1	0.560	2.340	
Part 2 e (2)	1.345	1.36	0.980	1	0.322	3.837	
Part 2 e (3)	0.376	0.99	0.144	1	0.705	1.457	
Part 2 e (4)	-0.181	0.94	0.037	1	0.847	0.834	
Part 2 e (5)	-0.919	0.92	0.992	1	0.319	0.399	
Part 2 e (6)	0.240	0.95	0.063	1	0.801	1.271	
Part 2 h ii	-1.275	0.60	4.525	1	0.033	0.279	X_1
Part 3 a	0.027	0.01	11.062	1	0.001	1.028	X_2
Part 4 b	1.981	0.60	10.783	1	0.001	7.252	X_3
Part 5 a	-0.105	0.03	9.355	1	0.002	0.900	X_4
Part 5 c	0.033	0.02	3.992	1	0.046	1.034	X_5
Constant	215.502	50.04	18.547	1	0.000	3.904E+93	β_0

The Negelkerke's R-square for this binary logistic regression is 0.474.

$$\hat{p}_{11} = \frac{e^{(215.502 - 1.275X_1 + 0.027X_2 + 1.981X_3 - 0.105X_4 + 0.033X_5)}}{1 + e^{(215.502 - 1.275X_1 + 0.027X_2 + 1.981X_3 - 0.105X_4 + 0.033X_5)}} \qquad (4.16)$$

4.2.12 Binary Logistic Regression Y_{12}

Table 79: Description of predictors related to Y_{12}

Predictor (address of the question)		*Pearson correlation*	*p-value*
(part 1 d)		-0.361	0.000
(part 2 e)		-0.379	0.000
Dramatically uncomfortable	(1)		
Very uncomfortable	(2)		
Uncomfortable	(3)		
Normal	(4)		
Comfortable	(5)		
Very comfortable	(6)		
Extremely comfortable	(7)		
(part 2 f)		-0.307	0.000
(part 2 g)		-0.103	0.000
(part 2 h ii)		-0.128	0.012
(part 3 a)		0.339	0.000
(part 3 e ii)		-0.102	0.045
(part 5 a)		-0.502	0.000

Table 80: Classification table

		Predicted outcome for Y_{12} question		percentage correct
		No	Yes	
Observed outcome for Y_{12} question	No	201	11	94.8
	Yes	19	153	89.0
			Overall percentage	92.2

Table 81: Results of binary logistic regression for Y_{12}

Predictors	*Coefficient*	*Standard error*	*Wald value*	*Df*	*P-value*	*Odds ratio*	*Label*
Part 1 d	-0.052	0.023	5.261	1	0.022	0.950	X_1
Part 2 e			37.725	6	0.000		
Part 2 e (1)	4.581	1.469	9.724	1	0.002	97.580	X_2
Part 2 e (2)	5.471	1.211	20.417	1	0.000	237.772	X_3
Part 2 e (3)	3.579	1.128	10.066	1	0.002	35.847	X_4
Part 2 e (4)	2.808	1.057	7.054	1	0.008	16.582	X_5
Part 2 e (5)	1.868	1.060	3.104	1	0.078	6.477	X_6
Part 2 e (6)	1.197	1.019	1.381	1	0.240	3.310	X_7
Part 2 g	-2.759	0.775	12.674	1	0.000	0.063	X_8
Part 2 h ii	-0.249	0.483	0.266	1	0.606	0.780	
Part 3 a	0.018	0.363	0.002	1	0.962	1.018	
Part 3 e ii	0.057	0.008	47.726	1	0.000	1.059	X_9
Part 5 a	-0.010	0.023	0.173	1	0.677	0.990	
Constant	442.822	54.434	66.179	1	0.000	2.065E+192	β_0

The Negelkerke's R-square for this binary logistic regression is 0.706.

$$\hat{p}_{12} = \frac{e^{(442.822-0.052X_1+4.581X_2+5.471X_3-3.579X_4+2.808X_5+1.868X_6+1.197X_7-2.759X_8+0.057X_9)}}{1+e^{(442.822-0.052X_1+4.581X_2+5.471X_3-3.579X_4+2.808X_5+1.868X_6+1.197X_7-2.759X_8+0.057X_9)}} \quad (4.17)$$

4.2.13 Binary Logistic Regression Y_{13}

Table 82: Description of predictors related to Y_{13}

Predictor (address of the question)	*Pearson correlation*	*p-value*
(part 1 d)	-0.207	0.000
(part 2 f)	-0.164	0.001
(part 2 g)	-0.124	0.015
(part 3 a)	0.107	0.035
(part 5 a)	-0.286	0.000
(part 5 f)	0.101	0.049

Table 83: Classification table

		Predicted outcome for Y_{13} question		percentage correct
		No	Yes	
Observed outcome for Y_{13} question	No	134	55	70.9
	Yes	65	130	66.7
			Overall percentage	68.8

Table 84: Results of binary logistic regression for Y_{13}

Predictors	***Coefficient***	***Standard error***	***Wald value***	***Df***	***P-value***	***Odds ratio***	***Label***
Part 1 d	-0.009	0.015	0.387	1	0.534	0.991	
Part 2 f	-1.041	0.373	7.790	1	0.005	0.353	X_1
Part 2 g	-0.869	0.321	7.333	1	0.007	0.419	X_2
Part 3 a	0.007	0.004	3.201	1	0.074	1.007	
Part 5 a	-0.055	0.014	16.024	1	0.000	0.964	X_3
Part 5 f	0.318	0.184	2.974	1	0.085	1.374	
Constant	128.074	25.093	26.050	1	0.000	4.187E+55	β_0

The Negelkerke's R-square for this binary logistic regression is 0.188.

$$\hat{p}_{13} = \frac{e^{(128.074-1.041X_1-0.869X_2-0.055X_3)}}{1+e^{(128.074-1.041X_1-0.869X_2-0.055X_3)}} \qquad (4.18)$$

4.2.14 Binary Logistic Regression Y_{14}

Table 85: Description of predictors related to Y_{14}

Predictor (address of the question)	*Pearson correlation*	*p-value*
(part 2 f)	-0.115	0.024

Table 86: Classification table

		Predicted outcome for Y_{14} question		percentage correct
		No	Yes	
Observed outcome for Y_{14} question	No	338	0	100.0
	Yes	46	0	0
			Overall percentage	88.0

Table 87: Results of binary logistic regression for Y_{14}

Predictors	*Coefficient*	*Standard error*	*Wald value*	*Df*	*P-value*	*Odds ratio*	*Label*
Part 2 f	-0.877	0.400	4.823	1	0.028	0.416	X_1
Constant	-1.253	0.359	12.207	1	0.000	0.286	β_0

The Negelkerke's R-square for this binary logistic regression is 0.021.

$$\hat{p}_{14} = \frac{e^{(-1.253-0.877X_1)}}{1+e^{(-1.253-0.877X_1)}} \quad (4.19)$$

4.2.15 Binary Logistic Regression Y_{15}

Table 88: Description of predictors related to Y_{15}

Predictor (address of the question)	*Pearson correlation*	*p-value*
(part 1 d)	-0.412	0.000
(part 2 h i)	-0.110	0.031
(part 5 a)	-0.483	0.000

Table 89: Classification table

		Predicted outcome for Y_{15} question		percentage correct
		No	Yes	
Observed outcome for Y_{15} question	No	333	7	97.9
	Yes	20	24	54.5
			Overall percentage	93.0

Table 90: Results of binary logistic regression for Y_{15}

Predictors	*Coefficient*	*Standard error*	*Wald value*	*Df*	*P-value*	*Odds ratio*	*Label*
Part 1 d	-0.082	0.023	12.362	1	0.000	0.922	X_1
Part 2 h i	-19.112	6007.135	0.000	1	0.997	0.000	
Part 5 a	-0.178	0.028	41.251	1	0.000	0.837	X_2
Constant	511.320	71.635	50.494	1	0.000	1.157E+222	β_0

The Negelkerke's R-square for this binary logistic regression is 0.546.

$$\hat{p}_{15} = \frac{e^{(511.320-0.082X_1-0.178X_2)}}{1+e^{(511.320-0.082X_1-0.178X_2)}} \tag{4.20}$$

4.2.16 Binary Logistic Regression Y_{16}

Table 91: Description of predictors related to Y_{16}

Predictor (address of the question)		*Pearson correlation*	*p-value*
(part 2 e)		-0.372	0.000
Dramatically uncomfortable	(1)		
Very uncomfortable	(2)		
Uncomfortable	(3)		
Normal	(4)		
Comfortable	(5)		
Very comfortable	(6)		
Extremely comfortable	(7)		
(part 2 g)		-0.141	0.000
(part 2 h ii)		-0.543	0.000
(part 4 b)		0.379	0.000
(part 5 a)		-0.192	0.000

Table 92: Classification table

		Predicted outcome for Y_{16} question		percentage correct
		No	Yes	
Observed outcome for Y_{16} question	No	244	32	88.4
	Yes	31	77	71.3
			Overall percentage	83.6

Table 93: Results of binary logistic regression for Y_{16}

Predictors	*Coefficient*	*Standard error*	*Wald value*	*Df*	*P-value*	*Odds ratio*	*Label*
Part 2 e			16.407	6	0.012		
Part 2 e (1)	20.197	8694.855	0.000	1	0.998	590580515.3	X_1
Part 2 e (2)	16.518	8694.855	0.000	1	0.998	350733230.2	X_2
Part 2 e (3)	-0.193	8694.855	0.000	1	0.998	472670071.5	X_3
Part 2 e (4)	0.031	8694.855	0.000	1	0.998	146163648.8	X_4
Part 2 e (5)	-1.807	8694.855	0.000	1	0.998	145800550.7	X_5
Part 2 e (6)	0.508	8694.855	0.000	1	0.998	81156745.6	X_6
Part 2 g	-0.569	0.419	1.845	1	0.556	0.249	
Part 2 h ii	-2.859	0.525	29.700	1	0.000	0.057	X_7
Part 4 b	0.830	0.443	3.506	1	0.061	2.293	
Part 5 a	-0.058	0.015	15.165	1	0.000	0.944	X_8
Constant	94.410	8694.904	0.000	1	0.991	1.004E+41	

The Negelkerke's R-square for this binary logistic regression is 0.537.

$$\hat{p}_{16} = \frac{e^{(20.197X_1+16.518X_2-0.193X_3+0.031X_4-1.807X_5+0.508X_6-2.859X_7-0.058X_8)}}{1+e^{(20.197X_1+16.518X_2-0.193X_3+0.031X_4-1.807X_5+0.508X_6-2.859X_7-0.058X_8)}} \tag{4.21}$$

4.2.17 Binary Logistic Regression Y_{17}

Table 94: Description of predictors related to Y_{17}

Predictor (address of the question)	*Pearson correlation*	*p-value*
(part 1 d)	-0.152	0.003
(part 2 h ii)	-0.577	0.000
(part 3 e ii)	-0.116	0.024
(part 4 b)	0.843	0.000
(part 5 a)	-0.111	0.030
(part 5 c)	0.226	0.000
(part 5 d)	-0.111	0.030

Table 95: Classification table

		Predicted outcome for Y_{17} question		percentage correct
		No	Yes	
Observed outcome for Y_{17} question	No	157	30	84.0
	Yes	1	195	99.5
			Overall percentage	91.9

Table 96: Results of binary logistic regression for Y_{17}

Predictors	***Coefficient***	***Standard error***	***Wald value***	***Df***	***P-value***	***Odds ratio***	***Label***
Part 1 d	-0.055	0.025	4.744	1	0.029	0.964	X_1
Part 2 h ii	-1.458	0.448	10.576	1	0.001	0.233	X_2
Part 3 e ii	-0.006	0.026	0.048	1	0.827	0.994	
Part 4 b	6.243	1.041	35.954	1	0.000	514.390	X_3
Part 5 a	0.027	0.020	1.896	1	0.169	1.028	
Part 5 c	0.015	0.015	1.052	1	0.305	1.015	
Constant	51.438	45.740	1.256	1	0.261	2.185E+22	

The Negelkerke's R-square for this binary logistic regression is 0.804.

$$\hat{p}_{17} = \frac{e^{(-0.055X_1 - 1.458X_2 + 6.243X_3)}}{1 + e^{(-0.055X_1 - 1.458X_2 + 6.243X_3)}} \qquad (4.22)$$

The same as Y_7, Y_{17} is run one more time without considering the part 4 b question in the model and the results as follows:

Table 97: Classification table

		Predicted outcome for Y_{17} question		percentage correct
		No	Yes	
Observed outcome for Y_{17} question	No	150	37	80.2
	Yes	38	158	80.6
			Overall percentage	80.4

Table 98: Results of binary logistic regression for Y_{17}

Predictors	*Coefficient*	*Standard error*	*Wald value*	*Df*	*P-value*	*Odds ratio*	*Label*
Part 1 d	-0.047	0.019	6.104	1	0.013	0.955	X_1
Part 2 h ii	-3.253	0.319	103.670	1	0.000	0.039	X_2
Part 3 e ii	-0.005	0.018	0.087	1	0.768	0.995	
Part 5 a	-0.007	0.016	0.184	1	0.668	0.993	
Part 5 c	0.064	0.011	33.454	1	0.000	1.066	X_3
Constant	103.108	30.777	11.223	1	0.001	6.016E+44	β_0

The Negelkerke's R-square for this binary logistic regression is 0.520.

$$\hat{p}_{17}{}' = \frac{e^{(103.108-0.047X_1-3.253X_2+0.064X_3)}}{1+e^{(103.108-0.047X_1-3.253X_2+0.064X_3)}} \qquad (4.23)$$

4.2.18 Binary Logistic Regression Y_{18}

According to Pearson correlation test, there is not any significantly correlated variable for this model; therefore, since there is no predictor to input for the binary logistic regression, no results is shown for the buttocks area discomfort during the last 7 days.

4.2.19 Binary Logistic Regression Y_{19}

Table 99: Description of predictors related to Y_{19}

Predictor (address of the question)	*Pearson correlation*	*p-value*
(part 1 d)	-0.376	0.000
(part 3 a)	0.262	0.000
(part 4 b)	0.130	0.011
(part 5 a)	-0.528	0.000
(part 5 c)	0.189	0.000

Table 100: Classification table

		Predicted outcome for Y_{19} question		percentage correct
		No	Yes	
Observed outcome for Y_{19} question	No	205	30	87.2
	Yes	43	106	71.1
			Overall percentage	81.0

Table 101: Results of binary logistic regression for Y_{19}

Predictors	Coefficient	Standard error	Wald value	Df	P-value	Odds ratio	Label
Part 1 d	-0.020	0.018	1.204	1	0.273	0.981	
Part 3 a	0.026	0.005	25.842	1	0.000	1.026	X_1
Part 4 b	0.009	0.286	0.001	1	0.975	1.009	
Part 5 a	-0.142	0.020	51.728	1	0.000	0.867	X_2
Part 5 c	0.046	0.011	18.279	1	0.000	1.047	X_3
Constant	312.981	38.011	67.798	1	0.000	8.430E+135	β_0

The Negelkerke's R-square for this binary logistic regression is 0.498.

$$\hat{p}_{19} = \frac{e^{(312.981-0.026X_1-0.142X_2+0.046X_3)}}{1+e^{(312.981-0.026X_1-0.142X_2+0.046X_3)}} \quad (4.24)$$

4.2.20 Binary Logistic Regression Y_{20}

According to Pearson correlation test, there is not any significantly correlated variable for this model; therefore, since there is no predictor to input for the binary logistic regression, no results is shown for the buttocks area discomfort during the last 7 days.

4.3 REBA Outcomes

The first position is selected based on the most awkward posture of the heavy truck drives body. Figure 13 shows the most awkward posture among drivers. Drivers use this position in order to see or reach and grab something under the container of their trucks.

The REBA score for this position is calculated as follow:

- *Step 1.* The neck position is bended less than 20 degree, twisted and side bended; therefore, neck score is 3.
- *Step 2.* Trunk is bended more than 60 degree, twisted and side bended; thus, trunk score is 5.

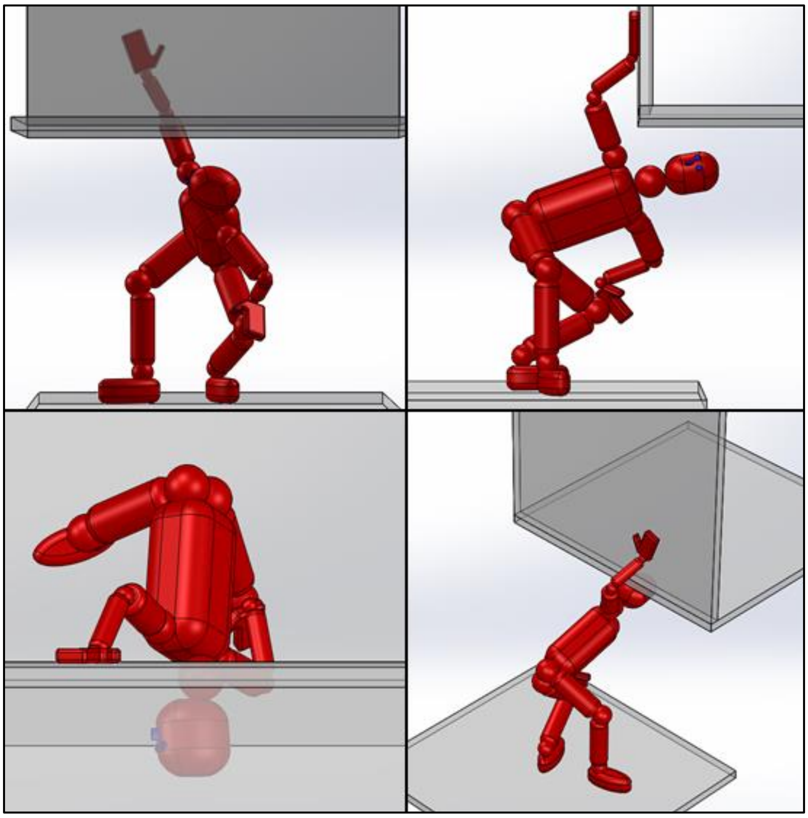

Figure 13: The most awkward position observed

- *Step 3.* Legs are not adjusted, and both bended more than 60 degree; so, score of the legs is 4.
- *Step 4.* Table A of the REBA worksheet demonstrates the poster score. The posture score A is equal to 9.
- *Step 5.* Since there is not any load on this posture, Force/Load score is 0.
- *Step 6.* By adding the value of *step 4 and 5* together the result is equal to 9.

- *Step 7.* Shoulder is abducted, raised and lifted more than 90 degree; therefore, the score is 6.
- *Step 8.* Lower arm is bended between 60 and 100 degree; therefore, lower arm score is 1.
- *Step 9.* Both wrists are bended more than 15 degrees; so, the score is 2.
- *Step 10.* According to steps 7- 9 Table B score is 8.
- *Step 11.* The hand hold is fair; thus, one point must be added to Table B score. The score B is equal to 10.
- *Step 12.* Table A and B would results the Table C score; for this posture this score is 12.
- *Step 13.* Since this position causes rapid changes in drivers' body posture and is unstable base, one more point must be added to Table C. Consequently, the REBA score related to this position is 13.

This REBA score is higher than 11 and this category of needs for immediate change or improvement in order to prevent any musculoskeletal discomfort. Figure 14 represents the improvement of Figure 13 position.

13 steps of the worksheets are run for this updated version which is as follows:

- *Step 1.* The neck is in exertion and the score related to it is 2.
- *Step 2.* Trunk is bended more than 60 degrees; thus, trunk score is 4.
- *Step 3.* Legs are adjusted, and both bended more than 60 degree; so, score of the legs is 2.
- *Step 4.* Table A of the REBA worksheet demonstrates the poster score. The posture score A is equal to 6.

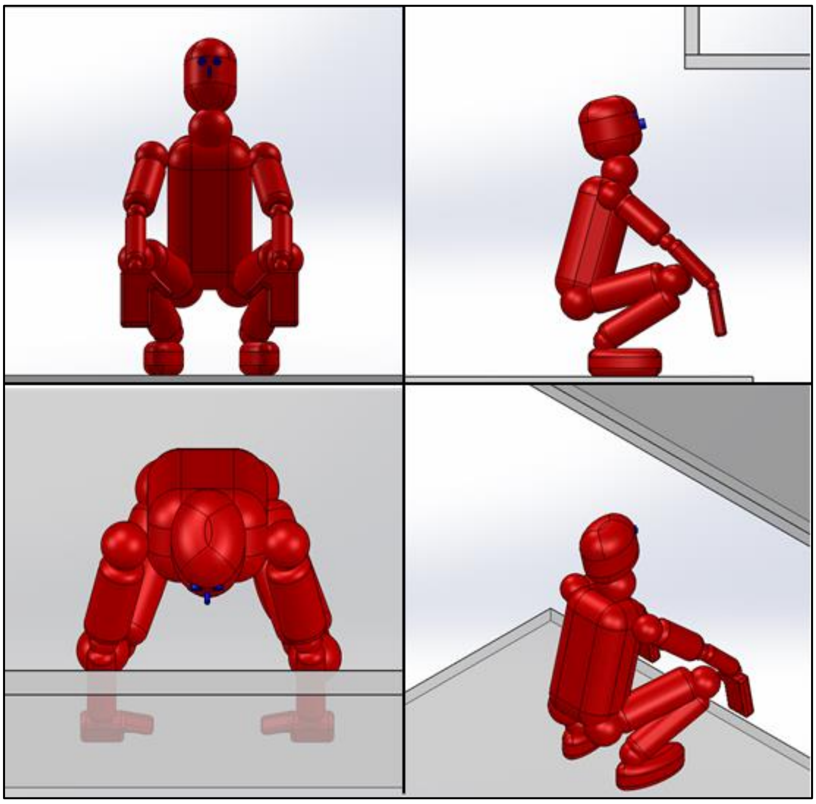

Figure 14: The most awkward position observed (improvement)

- *Step 5.* Since there is not any load on this posture, Force/Load score is 0.
- *Step 6.* By adding the value of *step 4 and 5* together the result is equal to 6.
- *Step 7.* Shoulder is lifted between 45 and 90 degree; therefore, the score is 4.
- *Step 8.* Lower arm is bended less than degree; therefore, lower arm score is 2.
- *Step 9.* Wrists are within $\pm$ 15 degrees; so, the score is 1.
- *Step 10.* According to steps 7- 9 Table B score is 5.
- *Step 11.* The hand hold is good; thus, no point needed be added to Table B score. The score B is equal to 5.
- *Step 12.* Table A and B would results the Table C score; for this posture this score is 8.

- *Step 13.* Since this position causes rapid changes in drivers' body posture and is unstable base, one more point must be added to Table C. Consequently, the REBA score related to this position is 9.

This position reduced 5 points from the Figure 13 position and changed the category from fifth to forth category. But it should be mention that further investigation is needed and changes must be improved even more.

Figure 15 demonstrates the position in which most louds must be handled by truck drivers.

For this position, it has been observed that the truck drivers carry more than 20 Kilograms (Kg) of weight as a tool box for maintenance of the truck. They mostly put the toolbox on their shoulders and support it with their hand. In order to balance their body mass they bend their entire body to the opposite side which causes a bad posture to carry heavy weights.

The REBA score for this position is calculated as follows:

- *Step 1.* The neck is side bended; therefore, neck score is 1.
- *Step 2.* Trunk is side bended; thus, trunk score is 2.
- *Step 3.* Legs are not adjusted; so, score of the legs is 2.
- *Step 4.* Table A of the REBA worksheet demonstrates the poster score. The posture score A is equal to 3.
- *Step 5.* Since drivers carrying weights more than 22 lbs. (>10Kg), 2 points must be considered.
- *Step 6.* By adding the value of *step 4 and 5* together the A score is equal to 5.

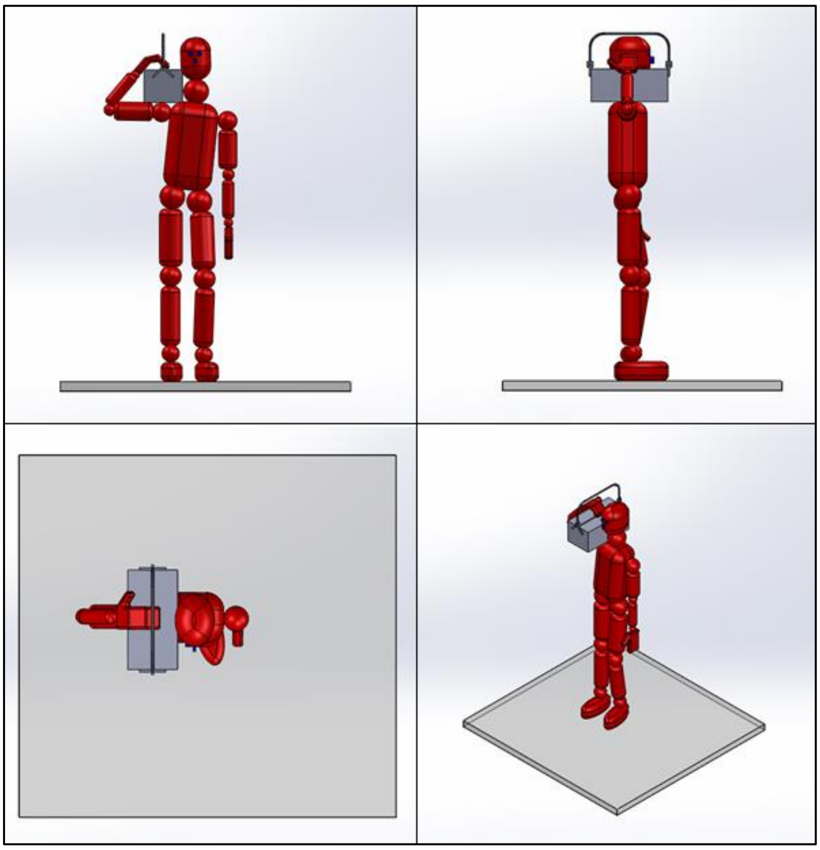

Figure 15: The heavy weight posture

- *Step 7.* Shoulder is raised, abducted and located in the range of 45 to 90 degree comparing to the middle body; therefore, the score is 5.
- *Step 8.* Lower arm is bended more than 100 degrees; therefore, lower arm score is 2.
- *Step 9.* Wrist is exceeded 15 degree range; so, the score is 2.
- *Step 10.* According to steps 7- 9 Table B score is 8.
- *Step 11.* The hand hold is not acceptable but possible; thus, 2 points needed to be added to Table B score; so, B score is 10.
- *Step 12.* Table A and B would results the Table C score; for this posture this score is 9.

- *Step 13.* Since this position causes sudden changes in drivers' body posture (lifting the weight up to shoulders height), one more point must be added to Table C. Consequently, the REBA score related to this position is 10.

The REBA score of 10 counts as a high risk position and changes must be implemented on it. Figure 16 shows the improved posture of this specific posture.

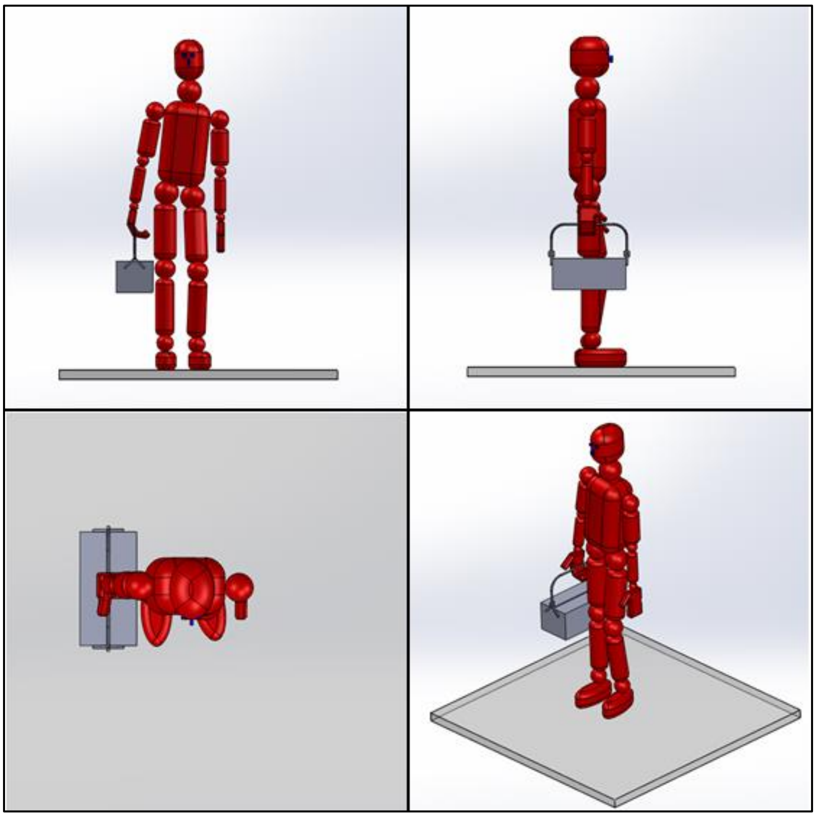
Figure 16: The heavy weight posture (Improved)

The REBA score for this position is calculated as follows:

- *Step 1.* The neck is side bended; therefore, neck score is 1.
- *Step 2.* Trunk is side bended; thus, trunk score is 2.
- *Step 3.* Legs are not adjusted; so, score of the legs is 2.

- *Step 4.*Table A of the REBA worksheet demonstrates the poster score. The posture score A is equal to 3.
- *Step 5.* Since drivers carrying weights more than 22 libra (lbs.) (>10Kg), 2 points must be considered.
- *Step 6.* By adding the value of *step 4 and 5* together the result is equal to 5.
- *Step 7.* Shoulder is raised and located in 20 degree of the middle; therefore, the score is 2.
- *Step 8.* Lower arm is bended less than degree; therefore, lower arm score is 2.
- *Step 9.* Both wrists are within the range of 15 degrees in each side; so, the score is 1.
- *Step 10.* According to steps 7- 9 Table B score is 2.
- *Step 11.* The hand hold is not acceptable but possible; thus, 2 points needed to be added to Table B score and therefore B score is 4.
- *Step 12.* Table A and B would results the Table C score; for this posture this score is 5.
- *Step 13.* Since this position causes no rapid changes in drivers' body posture and is stable base, no more point must be added to Table C. Consequently, the REBA score related to this position is 5.

This posture is categorized as medium risk position and soon must be changed. However, 5 points have already reduced comparing to Figure 15.

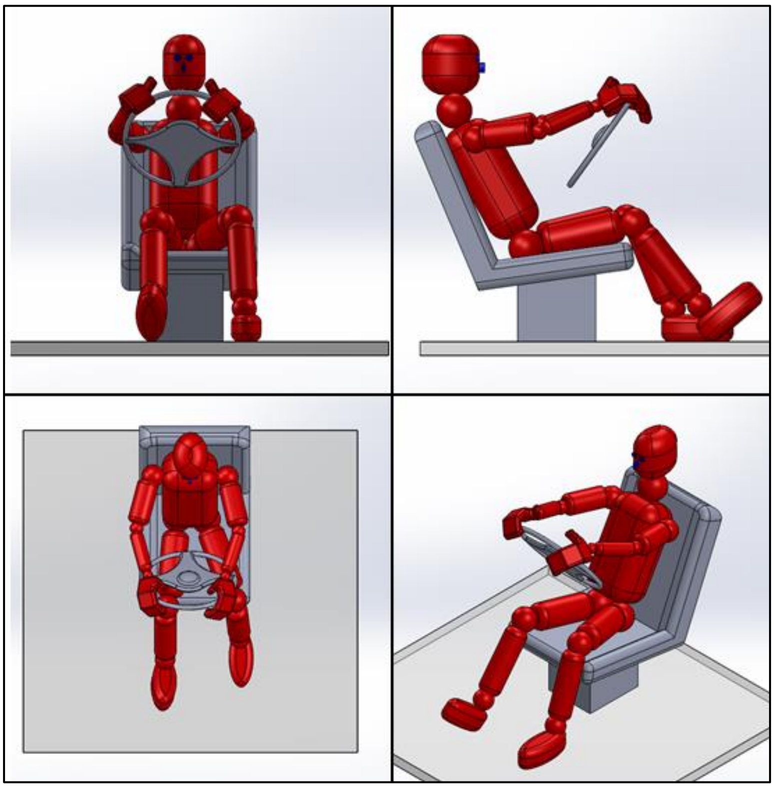

Figure 17: The most constant position

The most constant and the main posture of the truck drives is gathered in Figure 17. This position is when the drivers are behind the wheel. Since drivers must be in the same position for most of the working hours, implementing the improvement is very critical for this position.

The REBA score for this position is calculated as follows:

- *Step 1.* The neck is bended within the range of 10 to 20 degree; therefore, neck score is 1.
- *Step 2.* Trunk is bended more than 60 degrees; thus, trunk score is 4.
- *Step 3.* Legs are not adjusted and both legs are bended more than 60 degrees; thus, score of the legs is 4.
- *Step 4.* Table A of the REBA worksheet demonstrates the poster score. The score of Table A is equal to 7.

- *Step 5.* One point must be considered since drivers are exposed to WBV.
- *Step 6.* By adding the value of *step 4 and 5* together the A score is equal to 8.
- *Step 7.* Shoulder is abducted and located in the range of 45 to 90 degree comparing to the middle body; therefore, the score is 4.
- *Step 8.* Lower arm is bended less than 60 degrees; therefore, lower arm score is 2.
- *Step 9.* Wrists are exceeded 15 degree range and also bended from the middle; so, the score is 3.
- *Step 10.* According to steps 7- 9 Table B score is 7.
- *Step 11.* The steering wheel handled perfectly; thus, no more points needed to be added to Table B score; so, B score is 7.
- *Step 12.* Table A and B would results the Table C score; for this posture this score is 10.
- *Step 13.* Since this position requires repeated small actions and the body must be hold in a constant position, two more points must be added to Table C. Consequently, the REBA score related to this position is 12.

Score 12 would put this position in the very high risk category and changes must be implemented immediately. Since there is not enough space to change the characteristics of this position the only improvement is applied about the grapping of steering wheel. This improvement is illustrated in Figure19.

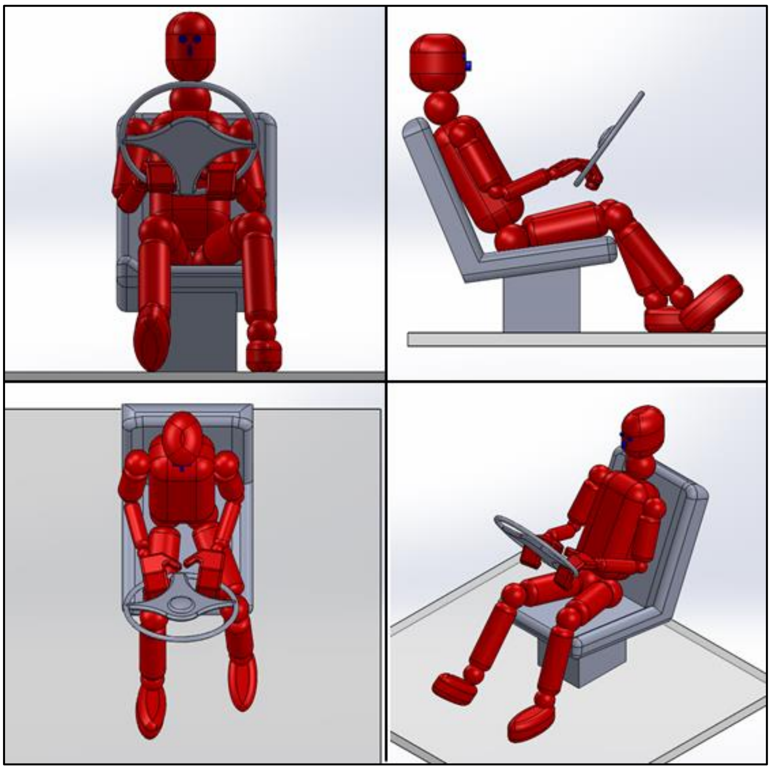

Figure 18: The most constant position (improved)

The REBA score for this position is calculated as follows:

- *Step 1.* The neck is bended within the range of 10 to 20 degree; therefore, neck score is 1.
- *Step 2.* Trunk is bended more than 60 degrees; thus, trunk score is 4.
- *Step 3.* Legs are not adjusted and both legs are bended more than 60 degrees; thus, score of the legs is 4.
- *Step 4.* Table A of the REBA worksheet demonstrates the poster score. The score of Table A is equal to 7.
- *Step 5.* One point must be considered since drivers are exposed to WBV.
- *Step 6.* By adding the value of *step 4* and *5* together the A score is equal to 8.
- *Step 7.* Shoulder is located in the range of 20 degree comparing to the middle body; therefore, the score is 1.

- *Step 8.* Lower arm is bended between 60 to 100 degrees; therefore, lower arm score is 1.
- *Step 9.* Wrists are exceeded 15 degree range and also bended from the middle; so, the score is 3.
- *Step 10.* According to steps 7- 9 Table B score is 3.
- *Step 11.* The steering wheel handled perfectly; thus, no more points needed to be added to Table B score; so, B score is 3.
- *Step 12.* Table A and B would results the Table C score; for this posture this score is 8.
- *Step 13.* The same as last position, two points must be added to Table C.

Consequently, the REBA score is 10. Comparing to the last position 2 points has been reduced and this score stays in high risk position instead.

Chapter 5

DISCUSSION

Related to first hypothesis which claims that there is an association between smoking status and discomfort of low back area which has been reported during the last 12 months among truck drivers, no association has been found between smoking and discomfort of lower back area (chi-square=0.414, P-value=0.813). However, the results retrieved by Ernst (1993) and Kilbom *et al.* (1996) show the association between smoking habit and LBP. But, they have already mentioned that it is unlikely for smoking to be the only factor of LBP.

In one hand, second hypothesis claims the association between weekly hours of exposure to vibration and discomfort of low back area which has been reported during the last 12 months among truck drivers. But, there was not enough evidence for the significant relation (chi-square=3.639, P-value=0.303). On the other hand, on several studies the association of these two factors has already been concluded (Bernard and Putz-Anderson, 1997; Bovenzi and Hulshof, 1998; Lings and Leboeuf-Yde, 2000; Mirzaei and Mohammadi, 2010; Sang *et al.*, 2010). This outcome could be caused by validation of the WBV part of the questionnaire. Since the interviewees where exposed to the vibration variously, the estimation could not be accurate enough for the WBV exposure. It is good to mentioned that in the study of Robb and Mansfield (2007), the distant factor is found more likely to be associated with MSDs than hours of exposure to vibration. However, the distance factor is not mentioned in their questionnaire; therefore, such information has not been collected from participants in this study.

Hours of exposure to vibration are associated with neck and shoulders discomfort of Iranian truck drivers (for neck: chi-square=54.568, p-value=0.000 and for shoulders: chi-square=31.811, p-value=0.000). This result is opposing to the other studies (Bernard and Putz-Anderson, 1997; Bovenzi and Hulshof, 1998).

Although Raanaas and Anderson (2008) has found the association between BMI and nightshift in their study, this association was not observed among heavy truck drivers of Iran (Fisher's exact=6.283, P-value=0.084).

The same as outcome in study of Robb and Mansfield (2007), most of the drivers are suffering from the lower back discomfort in Iran. According to Figure 1, out of 384 drivers who participated to this study 57% of them are experienced discomfort in their lower back area. A bar-chart with regards to this problem has been demonstrated about the prevalence of lower back discomfort. This chart has been illustrated by Robb and Mansfield (2007) as well. Figure 19 illustrates the prevalence of lower back discomfort of this study among others.

Figure 19 is sorted by the percentage of prevalence and as it is clarifies, Iranian truck drivers are ranked in 15th place (red bar). In this figure the studies were sorted from highest to lowest prevalence. It must be mentioned that Point Prevalence (PP), Regular (REG) and last 12 months (12m) are used by their abbreviations.

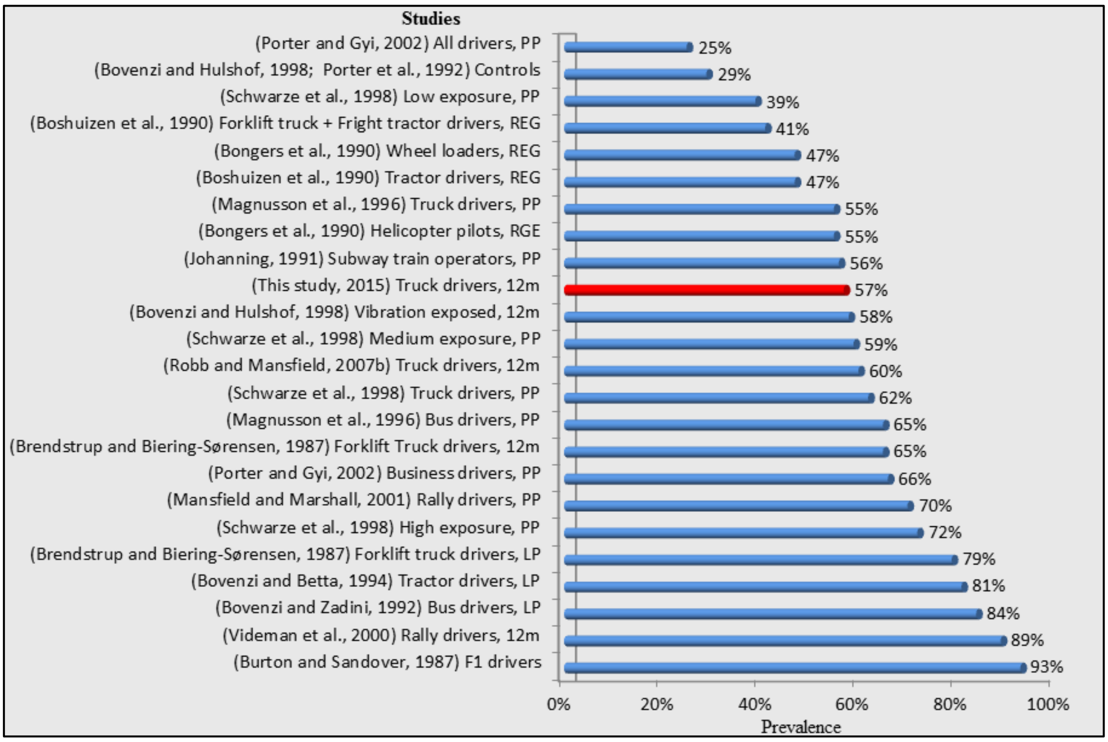

Figure 19: Prevalence of low back discomfort by studies

It was also revealed that by increasing of age, prevalence of musculoskeletal discomfort among truck drivers has been raised. Gangopadhyay *et al.* (2012) and Kilbom *et al.* (1996) have concluded the same results for the association of age and MSDs. The intensity of pain is highly associated with hours of which the drivers were prevented from work. In addition, experience of accident and weekly hours of exposure are highly associated with the number of body parts drivers experienced discomfort. The same results has been revealed by Robb and Mansfield (2007).

5.1 Limitation of this Study

Exposure to vibration most of the hypotheses outcomes in this research are in contrast with other studies. In order to find a better answer related to this factor more precise measurements are needed. Other than that, using an estimation of hours of exposure would not give an accurate outcome since the question contains materials which need interviewees to be well educated and this situation is not available among truck drivers of Iran.

Multinomial logistic regression model showed that, the prevalence of musculoskeletal discomfort is low, the variety of outcomes for different predictors are too low to be investigated. For instance in the ankles area the Negelkerke‘s R-square is 0.056 which is very low and it means that this model can explain 5.6% of the whole population (Bewick *et al.*, 2005). A much higher sample size would prevent such outcomes and would give more precise prediction.

5.2 Future Work

Cross sectional studies are limited with regards to their validation. Also, they are not able to investigate the effect of one or more factors on a dependent variable. In order to figure out this effect, more validated studies are needed to be installed for this study; although, it should be mentioned that cross sectional studies are very useful for creating hypotheses. For those hypotheses which there are evidence of significant associations, studies like Cohort and Case control can be implemented.

WBV have not been investigated completely in this research. The only question related to this force is the hours that drivers were on the truck and the engine was on. Instrumental assessment could be implemented for the better results related to this factor and its relation with musculoskeletal discomfort among truck drivers.

Iranian taxi drivers are the other population that this methodology could be applied on. Since they are exposed to physiological, psychological and psychosocial factors the same as truck drivers; prevalence of musculoskeletal among them must be investigated.

Chapter 6

CONCLUSION

This study has been implemented in order to investigate the musculoskeletal discomfort among truck drivers. Three basic factors of physiological, psychosocial and psychological are associated with these types of trouble. So far there has not been any research about the truck drivers and their musculoskeletal troubles in Iran. This research used 384 samples among them and it could be a good data base for further investigations.

Since the data has been collected in a specific time and there were no track of participants in a period of time, this study was limited to only finding the relation between factors. In other words, it is not clear whether factor A for example effects factor B or vice versa. The only clear claim is that factor A and B are associated with each other. However, cross sectional studies are able to be vastly analyzed different relationships among different factors. In another way, at the beginning of these types of methods, there are no certain outcomes expected. Since the same studies have already been applied in different geographical regions, some expectations with regards to them could be created before the data collection. In this study, 14 hypotheses have been claimed with regards to the previous researches and their outcomes. But, it does not necessarily mean that the same outcomes must be expected, which is already happened among these 14 hypotheses.

The type I error for all the hypotheses were set as 0.05 and those p-values which were less than 0.05 represent the significance of the related data. The findings of the thesis are explained as below.

H_1: No association has been found between smoking and low back discomfort. The method to test the related hypothesis was chi-square test of independence where the chi-square value and the p-value were 0.414 and 0.813 respectively.

H_2: There was not enough evidence to reveal an association between hours of exposure and the lower back discomfort. Chi-square test of independence was used to investigate the related hypothesis and the chi-square value and p-value were 3.639 and 0.303 in the order.

H_3: Neck discomfort was significantly associated with the hours of exposure to vibration. With chi-square value 54.568 and p-value of 0.000, the significant relation has been concluded.

H_4: The significant association between shoulders and hours of exposure to vibration is concluded from the chi-square test of independence. Chi-square value was 31.811 and the p-value was 0.000.

H_5: By the use of binomial proportion test, it was determined that most of the drivers were suffer from lower back discomfort in Iran. ($p = 0.5$ and p-value = 0.001)

H_6: there was found no relation between the BMI of the truck drivers and night shift working. Fisher's exact method was used where the chi-square value and the p-value related to this hypothesis were 6.283 and 0.084 respectively.

H_7: with Fisher's exact value of 38.789 and p-value of 0.000 for this hypothesis it was concluded that there is a significant relation between BMI and prevalence of lower back discomfort. According to Figure 5, by the increase of BMI among the truck drivers, the prevalence of lower back discomfort was increased.

H_8: A significant difference was found between different age categories and the prevalence of musculoskeletal discomfort among truck drivers (Welch value = 48.10 and p-value = 0.000).

H_9: It was concluded that there is a significant relation between the intensity of pain in lower back area and the days being prevented from the work (Fisher's exact value = 15.316 and p-value = 0.012)

H_{10}: Drivers, who experienced accident, significantly reported more body parts that they had trouble (F-value = 18.187 and p-value = 0.000).

H_{11}: By the increase of hours of exposure to vibration, there was a significant increase of number of body parts drivers experienced discomfort (F-value = 8.335 and p-value = 0.000)

H_{12}: there was a significant relation between discomfort of neck area and the seat comfort. (Chi-square value = 57.949 and p-value = 0.000). According to Figure 10, drivers who found their driver seats more comfortable were reported less discomfort of neck area.

H_{13}: seat comfort was significantly associated with the discomfort of shoulders. The Fisher exact value related to this hypothesis was 39.187 and the p-value was 0.000.

H_{14}: with chi-square value of 151.839 and p-value of 0.000 a significant relation between lower back pain and lumber support of driver's seat was concluded. According to Figure 12 drivers whom lumber support utilized on their seat experienced less low back discomfort.

By the use of logistic regression method significant mathematical models have been developed among Table in part4a of the questionnaire as the dependent variables and rest of the questions as predictors or independent variables.

Seat comfort is highly correlated with neck, shoulders and upper back areas. Drivers, who ranked higher points to their seat comfort, are less likely to report discomfort or problem in mentioned areas.

Age factor is also a significant predictor for the discomfort of neck, shoulder, elbows, wrists, upper back and knees. It is good to mention that, odds ratio is calculated by the formula 5.1.

$$\text{Odds ration} = \frac{Prob(Event)}{1-Prob(Event)} \qquad (5.1)$$

With odds ratios between 0 and 1, in binary logistic regression for age factor, it can be concluded that by the increase of date of birth, the likelihoods of reporting problem in neck, upper back and knees areas would decline. Since the multinomial logistic regression method is applied for shoulders, elbows and wrists, in which the reference of the comparison is the last category of the dependent variable (*yes in both sides*), more complex relation between age and the likelihood of discomfort, were observed.

Other than hypothesis testing method, since the data were mostly categorical, logistic regression method was used as well. This method helps to assess more deeply about the relations of different variables with each other. Also, a mathematical formula was created in order to have significant predictions with regards to the probability of having discomfort in a specific part of truck drivers' body. Moreover, Odds ratios collected from this survey were perfect and clear estimation of correlations among these factors.

Ironically, some factors were rarely expected to be significant predictors of musculoskeletal discomfort; however, the results demonstrate different perspective. For instance, weight of the truck drivers were highly correlated with the discomfort of lower back, knees and ankles. In opposite, working on nightshift was not associated with any musculoskeletal discomfort.

The questionnaire of this study was not able to cover the WBV factor correctly and in some cases different results were achieved which were not expected. For example there found no significant relation with WBV and lower back discomfort. Moreover, BMI is one of the most important factors which should be included in the questionnaire. Although it is not easy for participants to give such information, it can be easily calculated with the height and weight of each individual.

In the last part of the study REBA survey was implemented on different positions related to this occupation. Some unexpected outcomes have been estimated by the use of this method. Since truck drivers were mostly on the seating position for a long period of time, lots of ergonomic implementations are applied on the driver seat, yet the drivers are in danger of awkward posturing and its consequences. In addition, because there is not enough freedom behind the wheel for these occupational truck drivers, high concentration must be applied in order to improve such an issue in near future.

This study was able to achieve significant associations and correlations among different factors which may cause musculoskeletal discomforts in long term periods. And by using these associations and results assessment of reducing risk factors related to this issue can be implemented in the future.

At the end, collecting ergonomic information and implementing solutions with regards to possible problems in different occupation could results a better job efficiency and also more healthy population.

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APPENDICES

Appendix A: Updated Version of NMQ

WORK

1a. Are you currently employed?

☐ Yes ☐ No — *If **No**, please go to **Q4**.*

b. If Yes, what was your main **occupation** during the past week?

____

c. In what **industry** did you carry out this occupation? (eg. farming, quarrying, road haulage)

____

d. On what date did you start **in this industry**?

Month *(if known)*: ______ Year: _______

e. Does an average day involve lifting or moving weights of:

i). 20 lbs (10 kg) or mc   oy hand ☐ Yes ☐ No

ii). 56 lbs (25 kg) or more by hand ☐ Yes ☐ No

iii). Work on a night shift ☐ Yes ☐ No

VIBRATION EXPOSURE

2a. During the past week, did you drive, ride or stand on any kind of vehicle or machine at work?

☐ Yes ☐ No — *If **No**, please go to **Q4**.*

*If **Yes**, please give the following information:*

b. Vehicle type(s) *(eg. car, agricultural tractor, HGV, bus, off-road vehicle etc)* :

____

c. Make(s) and model(s) of vehicle(s) *(eg. Scania 143, Mercedes Atego, if known)*:

____

d. Year(s) of manufacture *(if known)*:

____

e. For the vehicle you used most, please circle or mark the **seat comfort** on the following **1-7** scale:

Very Comfortable	1	2	3	4	5	6	7	Very Uncomfortable

f. Does the vehicle you used most have a suspension seat?

☐ Yes ☐ No

g. If **Yes**, do you find this easy to adjust?

☐ Yes ☐ No

h. Does the drivers seat of the vehicle used most have:

i) armrests? ☐ Yes ☐ No

ii) an adjustable lumbar support ☐ Yes ☐ No

3a. For those machines or vehicles that you have just mentioned, we would like to know the total number of hours (or minutes) that you drove / rode / stood on them over the whole week. *(please count only the time that the ENGINE WAS RUNNING or POWER ON. If you cannot give the exact time, please give your best estimate).*

Name of machine / vehicle:	Time used in a typical week:	
1. ____________________	☐ hours	☐ mins
2. ____________________	☐ hours	☐ mins
3. ____________________	☐ hours	☐ mins
4. ____________________	☐ hours	☐ mins

b. Was the time you spent over the past week riding / driving / standing on such machines typical of the job?

☐ **Not applicable** (don't ride or drive vehicle or machine) ☐ **Yes** ☐ **No**

c. If No, in what way was it unusual?

____

d. In your main job, do you <u>ever</u> ride on / drive / stand on any other vehicles or machines that cause vibration or frequent jolting that you can feel ***(eg. vehicles only used occasionally or at certain times of the year)?***

☐ Yes ☐ No

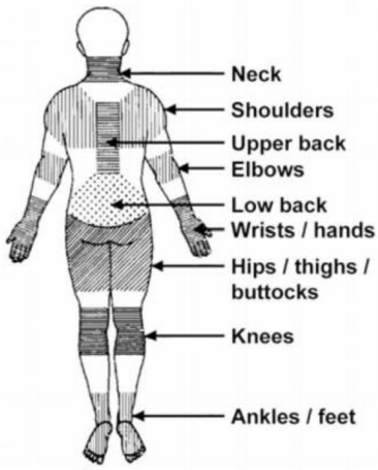
If Yes, which vehicles / machines? ______

____

e. In your spare time (ie. outside work and going to and from work, please estimate the <u>total number</u> of hours (or minutes) you spent driving or riding in the vehicles listed below. *If you cannot give the exact time, please give your best estimate.*

Car or Van	☐ hours ☐ mins	**Train**	☐ hours ☐ mins
Bus or Coach	☐ hours ☐ mins	**Motorcycle**	☐ hours ☐ mins

HEALTH



In the picture you can see the approximate position of the parts of the body referred to. Limits are not sharply defined and certain parts overlap. You should decide for yourself in which part you have or have had trouble (if any).

4a. Musculoskeletal problems

(Answer only if you have had trouble)	Have you at any time during the **last 12 months** had trouble (ache, pain, discomfort) in: Neck, Shoulders Elbows Wrists / Hands Upper back Lower back (small of the back) One or both hips / thighs One or both Knees One or both ankles / feet	Have you at any time during the **last 12 months** been prevented from doing your normal work (at home or away from home) because of the trouble?	Have you had trouble at any time during the **last 7 days**?
	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
	☐ No ☐ Yes, in right shoulder ☐ Yes, in left shoulder ☐ Yes, in both shoulders	☐ No ☐ Yes	☐ No ☐ Yes
	☐ No ☐ Yes, in right elbow ☐ Yes, in left elbow ☐ Yes, in both elbows	☐ No ☐ Yes	☐ No ☐ Yes
Wrists / hands	☐ No ☐ Yes, in right wrist/hand ☐ Yes, in left wrist/hand ☐ Yes, in both wrists/hands	☐ No ☐ Yes	☐ No ☐ Yes
Upper back	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
Lower back (small of the back)	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes
One or both ankles / feet	☐ No ☐ Yes	☐ No ☐ Yes	☐ No ☐ Yes

b. Have you **ever** had any low back trouble (ache, pain, numbness or discomfort)?

☐ Yes ☐ No — *If **No**, please go to **Q5a.***

c. Have you **ever** hurt your low back in an **accident**?

☐ Yes ☐ No

d. If **Yes**, was the accident at work?

☐ Yes ☐ No

what was the approximate **date** of the accident? ☐ month ☐ year

d. Have you **ever** had to change **jobs or duties** because of low back trouble?

☐ Yes ☐ No

e. What do you think brought on this problem with your back?

Accident ☐ Activity at Work ☐
Sporting Activity ☐ Other *(please specify)* ______________ ☐
Activity at Home ☐

____

f. How bad was the pain during the **worst** episode?

☐ Mild ☐ Severe ☐ Very, Very Severe

g. What is the **total** length of time you have had low back trouble during the **last 12 months?**

0 days ☐ — *If **0**, please go to **Q5a**.*
1-7 days ☐
8-30 days ☐
More than 30 days, but not every day ☐
Every day ☐

h. Has low back trouble caused you to reduce your activity during the **last 12 months?**

i) work activity ☐ Yes ☐ No
ii) leisure activity ☐ Yes ☐ No

i. What is the **total** length of time that low back trouble has prevented you from doing your normal work (at home or away from home) during the **last 12 months?**

0 days ☐
1-7 days ☐
8-30 days ☐
More than 30 days ☐

j. Have you **been seen** by a doctor, physiotherapist, chiropractor or other such person because of low back trouble during the **last 12 months?**

☐ Yes ☐ No

k. Please give details of any issues regarding vibration and back pain that have not been discussed by this questionnaire: __________

____

____

DETAILS

5a. Please fill in your date of birth: ☐ day ☐ month ☐ year

b. Sex: ☐ male ☐ female

c. What is your weight? ☐ stones ☐ pounds or ☐ kg

d. What is your height? ☐ feet ☐ inches or ☐ cm

e. Are you right or left handed?

☐ right ☐ left ☐ able to use both hands equally

f. Are you a:

☐ smoker ☐ non-smoker ☐ ex-smoker

Appendix B: Sample of NIOSH Symptoms Survey

Tray 4–A. Symptoms Survey Form

Symptoms Survey: *Ergonomics Program*

Date _____/_____/_____/

_____ Plant   _____ Dept #   Job Name ____________________

_____ Shift   __________ Hours worked/week   _____ years _____ months Time on THIS Job

Other jobs you have done in the last year (for more than 2 weeks)

_____ Plant   _____ Dept #   __________ Job Name   _____ months _____ weeks Time on THIS Job

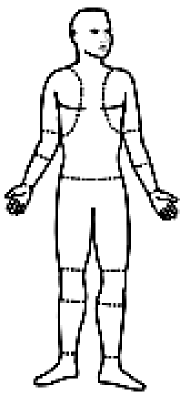
_____ Plant   _____ Dept #   __________ Job Name   _____ months _____ weeks Time on THIS Job

(If more than 2 jobs, include those you worked on the most)

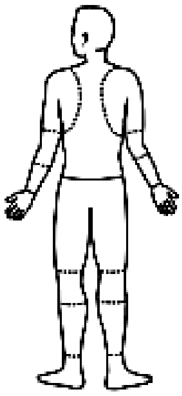
Have you had any pain or discomfort during the last year?

☐ Yes   ☐ No (If NO, stop here)

If YES, carefully shade in area of the drawing which bothers you the MOST.



Front



Back

(Continued)

Tray 4–A (Continued).

(Complete a separate page for each area that bothers you)

Check Area: ☐ Neck ☐ Shoulder ☐ Elbow/Forearm ☐ Hand/Wrist ☐ Fingers
☐ Upper Back ☐ Low Back ☐ Thigh/Knee ☐ Low Leg ☐ Ankle/Foot

1. Please put a check by the words(s) that best describe your problem

☐ Aching	☐ Numbness (asleep)	☐ Tingling
☐ Burning	☐ Pain	☐ Weakness
☐ Cramping	☐ Swelling	☐ Other
☐ Loss of Color	☐ Stiffness	

2. When did you first notice the problem?__________ (month)________ (year)

3. How long does each episode last? (Mark an X along the line)

_________/_________/_________/_________/_________/
1 hour 1 day 1 week 1 month 6 months

4. How many separate episodes have you had in the last year?____________________

5. What do you think caused the problem?____________________

6. Have you had this problem in the last 7 days? ☐ Yes ☐ No

7. How would you rate this problem? (mark an X on the line)
NOW
____
None Unbearable
When it is the WORST
____
None Unbearable

8. Have you had medical treatment for this problem? ☐ Yes ☐ No

8a. If NO, why not?____________________

8a. If YES, where did you receive treatment?

☐ 1. Company Medical Times in past year ____________
☐ 2. Personal doctor Times in past year ____________
☐ 3. Other Times in past year ____________

Did treatment help? ☐ Yes ☐ No ____________

9. How much time have you lost in the last year because of this problem?____ days

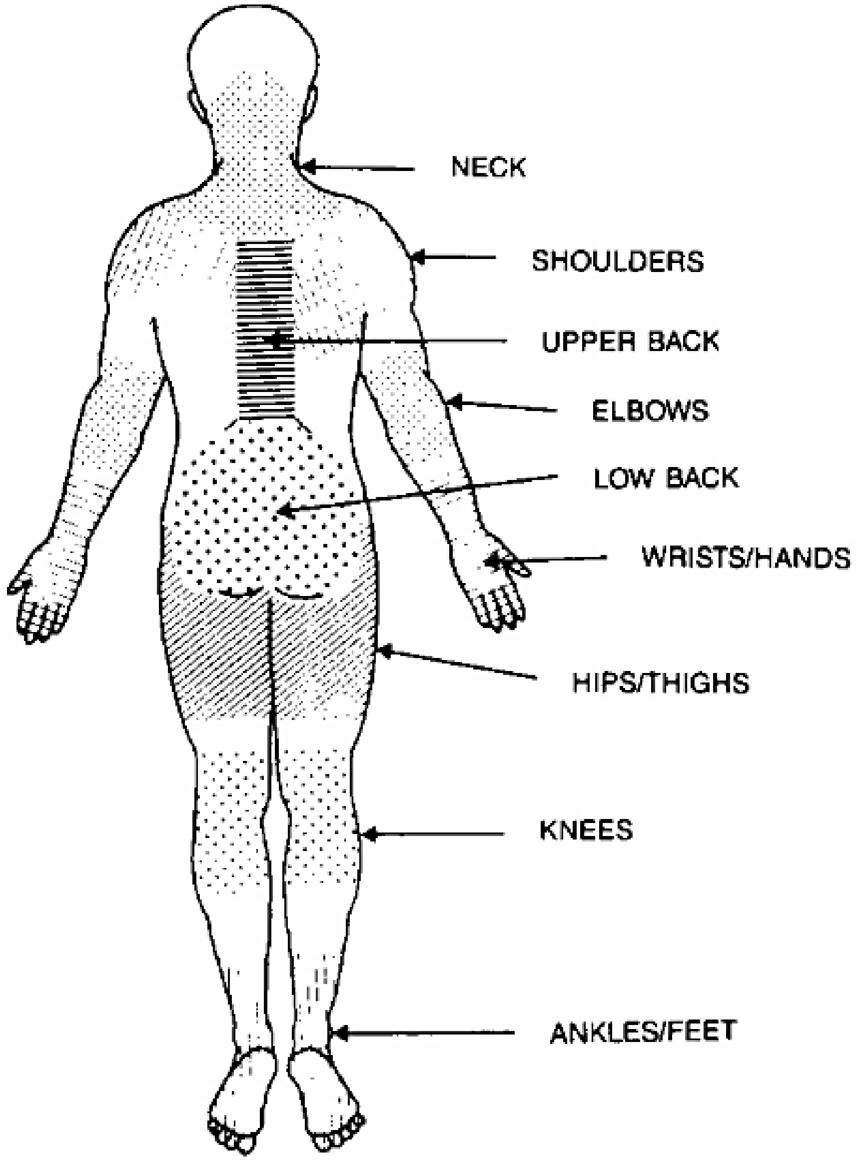
10. How many days in the last year were you on restricted or light duty because of this problem?
____ days

11. Please comment on what you think would improve your symptoms

____
____
____
____

How to answer the questionnaire:

Please answer by putting a cross in the appropriate box — one cross for each question. You may be in doubt as to how to answer, but please do your best anyway. Please answer every question, even if you have never had trouble in any part of your body.



In this picture you can see the approximate position of the parts of the body referred to in the questionnaire. Limits are not sharply defined, and certain parts overlap. You should decide for yourself in which part you have or have had your trouble (if any).

Appendix C: Sample of DMDQ

General questions

Please read the explanation on the previous page before answering the questions below!

1. What is your age? years

2. What is your gender? male 1 female 2

3. – Has your family lived in Britain for at least three generations? yes 1 no 2
 – Can you speak and read the English language easily? yes 1 no 2

4. What is the <u>highest</u> education that you completed succesfully?
 ? no education completed or primary school 1
 ? lower secondary or vocational school 2
 ? intermediate secondary or vocational school 3
 ? higher secondary or vocational school 4
 ? university 5

5. – How tall are you? about cm
 – What is your weight? about kg

6. –How many years have you been carrying out your present work at this firm? years
 – How many hours week do you work normally (*including regular overtime!*)? hours per week
 – How many days per week do you work normally? days per week

7. – Do you have a temporary contract (less than a year) or are you a temp.? yes 1 no 2
 – Are you on sick leave or partly disabled? yes 1 no 2
 – Do you have other jobs (paid or unpaid)? yes 1 no 2
 – Do you work left-handed? yes 1 no 2

8. Do you supervise people in your daily work? yes 1 no 2

9. How long does it take to travel to your work (single journey)? minutes

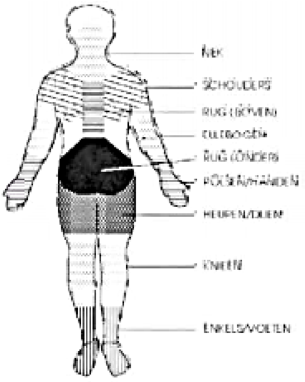
10. How do you usually travel to your work *(more than one answer is possible)?*
 on foot 1
 pushbike 1
 moped, motor 1
 car 1
 bus 1
 tram, train 1

11. Are you working in shifts?
 no 1
 yes, irregular shifts 2
 yes, 2 shifts (no nights) 3
 yes, 3 shifts 4
 yes, 12 hour shifts 5

Health (1)

1.	How is your health status in general?	good	1
		reasonably good	2
		not too bad	3
		poor	4
2.	How is to your opinion your physical fitness nowadays?	good	1
		reasonably good	2
		not too bad	3
		poor	4
3.	– Does your work require a lot of strength?	yes 1 no	2
	– Does your work require endurance?	yes 1 no	2
4.	How tired are you normally at the end of a working day physically?	not tired	1
		a bit tired	2
		rather tired	3
		very tired	4
5.	How tired are you normally at the end of a working day mentally?	not tired	1
		a bit tired	2
		rather tired	3
		very tired	4
6.	– Have you had any complaints about your health recently?	yes 1 no	2
	– Have you consulted your doctor the past six months (other than for a routine check-up)?	yes 1 no	2
	–Is a physician treating you at the moment?	yes 1 no	2
	– Have you been absent from work the last six months because of an illness or an accident?	yes 1 no	2
	– Are you taking drugs on a doctors prescription?	yes 1 no	2
7.	Do you smoke or did you smoke in the past?	yes, I'm smoking nowadays	1
		yes, I did smoke in the past	2
		no, I never smoked	3
8.	–Do you often feel tense?	yes 1 no	2
	– Do you often feel nervous?	yes 1 no	2
	– Do you often feel flustered?	yes 1 no	2
	– Are you often very tired after work?	yes 1 no	2
	– Do you regularly feel tired when getting up in the morning?	yes 1 no	2

Health (2)



1. Have you ever had trouble (pain, discomfort) from your:

? neck	? yes	1	no	2
? upper back	? yes	1	no	2
? lower back	? yes	1	no	2
? shoulders	? yes	1	no	2
? elbows	? yes	1	no	2
? wrists/hands	? yes	1	no	2
? hips/thighs	? yes	1	no	2
? knees	? yes	1	no	2
? ankles/feet	? yes	1	no	2

2. Have you had in the past 12 months trouble (pain, discomrort) from your:

	YES, sometimes	YES, regularly	YES, chronically	NO , never
? neck	1	2	3	4
? upper back	1	2	3	4
? lower back	1	2	3	4
? left shoulder	1	2	3	4
? right shoulder	1	2	3	4
? left elbow	1	2	3	4
? right elbow	1	2	3	4
? left wrist/hand	1	2	3	4
? right wrist/hand	1	2	3	4
? left hip/thigh	1	2	3	4
? right hip/thigh	1	2	3	4
? left knee	1	2	3	4
? right knee	1	2	3	4
? left ankle/foot	1	2	3	4
? right ankle/foot	1	2	3	4

3. Have you had during the past 7 days trouble (pain, discomfort) from your:

? neck	yes	1	no	2
? upper back	yes	1	no	2
? lower back	yes	1	no	2
? shoulders	yes	1	no	2
? elbows	yes	1	no	2
? wrists/hands	yes	1	no	2
? hips/thighs	yes	1	no	2
? knees	yes	1	no	2
? ankles/feet	yes	1	no	2

Work (1)

1. Please list your job tasks and indicate how often (seldom/never, sometimes, often or (almost) always?)

	seldom or never	sometimes	often	(almost) always
1.	1	2	3	4
2.	1	2	3	4
3.	1	2	3	4
4.	1	2	3	4
5.	1	2	3	4
6.	1	2	3	4
7.	1	2	3	4
8.	1	2	3	4
9.	1	2	3	4

2. Please mark for each task and all tasks together the number which best indicates the amount of exertion associated with that task (light, normal, heavy, very heavy).

	light	.	normal	.	heavy	.	very heavy
	1	2	3	4	5	6	7
The tasks should be the same as in the table above.							
1.	1	2	3	4	5	6	7
2.	1	2	3	4	5	6	7
3.	1	2	3	4	5	6	7
4.	1	2	3	4	5	6	7
5.	1	2	3	4	5	6	7
6.	1	2	3	4	5	6	7
7.	1	2	3	4	5	6	7
8.	1	2	3	4	5	6	7
9.	1	2	3	4	5	6	7
all tasks together, taking into account the frequency	1	2	3	4	5	6	7

Work (2)

1. – Do you carry out the same work almost the whole day? yes 1 no 2
   – Does your work vary from day to day? yes 1 no 2
   – Does the work rotate between you and your colleagues? yes 1 no 2
   – Do your tasks vary according to the season or time of the year? yes 1 no 2
   – Do you carry out your work mostly at the same workplace(s)? yes 1 no 2
   – Do you carry out your work outdoors? yes 1 no 2
   – Do you have a sedentary job? yes 1 no 2
   – Does your work involve mainly repetitive tasks many times a minute? yes 1 no 2
   – Does your work often involve contacts with clients, patients or the public? yes 1 no 2
   – Does your work involve coldness, draughts or changes of temperature? yes 1 no 2
   – Are you often driving in vehicles at your work? yes 1 no 2

2. *This question addresses breaks. We are only interested in breaks which you actually have or could take!*
   – How many breaks do you have during a normal working day? ? breaks per day
   –Counting all breaks, how many minutes resting time do you have normally? ? ? ? minutes per day
   – Are your normal breaks sufficient? yes 1 no 2
   – Are you going back to work rested after a break? yes 1 no 2

3. – Can you choose the start and end of a working day yourself? yes 1 no 2
   – Can you choose the moment of a break yourself? yes 1 no 2
   – Are you familiar with your work schedule longer than one month on forehand? yes 1 no 2
   – Can you take a holiday when you wish? yes 1 no 2
   – Is there a shortage of personnel at your department? yes 1 no 2
   – Do you have to replace colleagues often? yes 1 no 2
   – Do you have overtime regularly? yes 1 no 2

4. Did you have other work <u>in the past</u>? yes 1 no 2
   <u>If yes</u>: Which kind of work did you do in your previous work <u>never, sometimes, often or (almost) always</u>?

	seldom or never	some-times	often	almost always
standing for long periods	1	2	3	4
sitting for long periods	1	2	3	4
VDU work for long periods	1	2	3	4
squatting/kneeling for long periods	1	2	3	4
moving loads (more than 5 kg)	1	2	3	4
moving heavy loads (more than 20 kg)	1	2	3	4
jobs which require exertion of arms/hands	1	2	3	4
working with vibrating tools	1	2	3	4
driving vehicles	1	2	3	4
working in uncomfortable postures	1	2	3	4
working in the same position for long periods	1	2	3	4
doing repetitive tasks many times per minute	1	2	3	4

Work (3)

1.	Do you in your work often have to:				
	– lift heavy loads (more than 5 kg)?	yes	1	no	2
	– push or pull heavy loads (more than 5 kg)?	yes	1	no	2
	– carry heavy loads (more than 5 kg)?	yes	1	no	2
2.	Do you in your work often have to lift:				
	– in a uncomfortable position?	yes	1	no	2
	– with the load far away from your body?	yes	1	no	2
	– with twisted trunk?	yes	1	no	2
	– with the load above shoulder-level?	yes	1	no	2
	– with one hand?	yes	1	no	2
	– with a load which is difficult to grap or hold?	yes	1	no	2
3.	Do you in your work often have to:				
	– lift very heavy loads (more than 20 kg)?	yes	1	no	2
	– push or pull very heavy loads (more than 20 kg)?	yes	1	no	2
	– carry very heavy loads (more than 20 kg)?	yes	1	no	2
4.	Do you in your work often have to::				
	– bent slightly with your trunk?	yes	1	no	2
	– bent heavily with your trunk?	yes	1	no	2
	– twist slightly with your trunk??	yes	1	no	2
	– twist heavily with your trunk?	yes	1	no	2
	– bent and twist simultaneously with your trunk?	yes	1	no	2
5.	Do you in your work often have to work:				
	– in a slightly bent posture for long periods?	yes	1	no	2
	– in a heavily bent posture for long periods?	yes	1	no	2
	– in a slightly twisted posture for long periods?	yes	1	no	2
	– in a heavily twisted posture for long periods?	yes	1	no	2
	– in a bent and twisted for long periods?	yes	1	no	2
6.	Do you in your work often have to:				
	– bent your neck forward or hold your neck in a forward posture for long periods?	yes	1	no	2
	– bent your neck backward or hold your neck in a backward posture for long periods?	yes	1	no	2
	– twist your neck or hold your neck in a twisted posture for long periods?	yes	1	no	2
7.	Do you in your work often have to:				
	– bent your wrist or hold your wrist bent for long periods?	yes	1	no	2
	– twist your wrist or hold your wrist twisted for long periods?	yes	1	no	2
8.	Do you in your work often have to make:				
	– the same movements with your arms, hands of fingers many times per minute?	yes	1	no	2
	– the same movements (bending, twisting) with your trunk many times per minute?	yes	1	no	2
	– the same movements (bending, twisting) with your head many times per minute?	yes	1	no	2

Work (4)

1.	How many minutes per day do you work with your hands:				
	– above shoulder level?	about	minutes per day		
	– under knee level?	about	minutes per day		
	(if not applicable, insert a '0')				
2.	Do you in your work often have to:				
	– reach with your arms or hands?	yes	1	no	2
	– hold your hands at or under shoulder level?	yes	1	no	2
	– hold your hands above shoulder level?	yes	1	no	2
	– work in uncomfortable postures?	yes	1	no	2
3.	Do you in your work often have to:				
	– stand for long periods?	yes	1	no	2
	– sit for long periods?	yes	1	no	2
	– walk for long periods?	yes	1	no	2
	– work kneeled or squatted for long periods?	yes	1	no	2
	– work in the same posture for long periods?	yes	1	no	2
4.	Do you in your work often have to:				
	– sit on your knees of move on your knees?	yes	1	no	2
	– operate pedals with your feet?	yes	1	no	2
	– climb stairs?	yes	1	no	2
	– walk on irregular surfaces?	yes	1	no	2
	– lay on your back?	yes	1	no	2
5.	Do you in your work often hold vibrating tools?	yes	1	no	2
6.	Do you in your work often have:				
	– insufficient space to do your work properly?	yes	1	no	2
	– insufficient space above you which forces you to bent forward?	yes	1	no	2
	– insufficient height or reach to be able to reach things with your tools?	yes	1	no	2
7.	Do you in your work often have:				
	– difficulties exerting enough force because of uncomfortable postures?	yes	1	no	2
	– nothing to lean on?	yes	1	no	2
8.	Do you in your work often have to:				
	– make sudden, unexpected movements?	yes	1	no	2
	– perform short, but maximal force-exertions?	yes	1	no	2
	– exert great force with your arms or hands?	yes	1	no	2
	– hold things in a pinch grip with your hands?	yes	1	no	2
	– exert great force on tools or machinery?	yes	1	no	2
9.	Do you sometimes slip or fall during your work?	yes	1	no	2

Work (5)

1.	– Is your work physically very strenuous?	yes	1	no	2
	– Is your work mentally very exacting?	yes	1	no	2
2.	Does your work cause you to perspire or to be out of breath?	yes	1	no	2
3.	– Is the rate at which or the pressure under which you have to work regularly fairly high?	yes	1	no	2
	– Are you regularly working under pressure of time?	yes	1	no	2
	– Do you have to hurry to be ready on time?	yes	1	no	2
	– Do you regularly have problems with the pace or the busyness of your work?	yes	1	no	2
	– Should you really be taking it somewhat easier in your work?	yes	1	no	2
	– is your work often too tiring?	yes	1	no	2
4.	– Do you have to work very fast?	yes	1	no	2
	– Do you have very much to do?	yes	1	no	2
	– Do you have to work extra hard?	yes	1	no	2
	– Do you have enough time in general to finish all your work in time?	yes	1	no	2
	– Is your work hectic or is it a madhouse?	yes	1	no	2
5.	– Can you determine yourself how to carry out your work?	yes	1	no	2
	– Are there in general enough tools available at your work	yes	1	no	2
	– Do you yourself determine the sequence of your tasks?	yes	1	no	2
	– Can you adjust your workplace yourself *(think of the height of e.g. your chair, table)*?	yes	1	no	2
	– Do you decide yourself when to carry out a task?	yes	1	no	2
	– Can you leave your workplace easily if you wish to do that?	yes	1	no	2
	– Can you interrupt your work if you wish to do that?	yes	1	no	2
	– Can you control your working pace yourself?	yes	1	no	2
6.	– Are you mentally exhausted by your work?	yes	1	no	2
	– Do you feel empty at the end of a working day?	yes	1	no	2
	– Do you feel tired when you wake up at the start of a new working day?	yes	1	no	2
	– Do you feel 'burned-out' by your work?	yes	1	no	2
	– Are you frustrated by your job?	yes	1	no	2
	– Do you think that you have too much to do at work?	yes	1	no	2
	– Do you feel things are too much for you?	yes	1	no	2
7.	– Is your work mostly interesting?	yes	1	no	2
	– Do you have enough variety in your work?	yes	1	no	2
	– Do you consider your work too simple?	yes	1	no	2
	– Do you have enough training to perform your tasks?	yes	1	no	2
	– Do you mostly enjoy your work?	yes	1	no	2

Work (6)

1.	Are you much hindered in your work by:				
	– noise?	yes	1	no	2
	– lack of fresh air?	yes	1	no	2
	– dry air?	yes	1	no	2
	– changes or extremes of temperature?	yes	1	no	2
	– bad smells or stench?	yes	1	no	2
2.	– Is your work often hampered by unexpected situations?	yes	1	no	2
	– Is your work usually well organized?	yes	1	no	2
	– Are their sufficient possibilities for consultation about your work?	yes	1	no	2
	– Is your work often hindered by the absence of others?	yes	1	no	2
	– Are you regularly hindered in your work by deficiencies in the work of others?	yes	1	no	2
3.	– Are you working under a good supervision?	yes	1	no	2
	– Are you often annoyed by others at your work?	yes	1	no	2
	– Does the supervision sufficiently regard what you say?	yes	1	no	2
	– Do you find the atmosphere at work all right?	yes	1	no	2
	– Does the supervision have a correct picture of you in your work?	yes	1	no	2
	– Does the supervision provide enough support in your work?	yes	1	no	2
	– Can you count upon the support of one of your colleagues if necessary?	yes	1	no	2
	– Are you kept informed on what is going on in your company?	yes	1	no	2
4.	– Are there circumstances in your work that adversely affect your private live?	yes	1	no	2
	– Are there circumstances in your private live that adversely affect your work?	yes	1	no	2
	– Do you take problems at work with you to your home?	yes	1	no	2
	– Do you take problems at home with you to your work?	yes	1	no	2
	– Do you consider the safety at work all right?	yes	1	no	2
	– Are your prospects good with this employer?	yes	1	no	2
	– Are there enough possibilities for a good career at your work?	yes	1	no	2
	– Do you feel that you are sufficiently valued in this company?	yes	1	no	2
	– Do you think your pay is appropriate for the work you are doing?	yes	1	no	2
5.	– Does your work require skills?	yes	1	no	2
	– Do you have enough variety in your work?	yes	1	no	2
	– Does your job require that you learn new things??	yes	1	no	2
	– Does your job require creativity?	yes	1	no	2
	– Do you have the opportunity to develop your skills?	yes	1	no	2
	– Do you have to carry out the same actions again and again over a short period of time?	yes	1	no	2
6.	All in all, does your work suit you well, reasonably well, not too badly or badly?	well	1		
		reasonably well	2		
		not too badly	3		
		badly	4		

Leisure time

1. Please indicate the number of hours per week you are travelling in a motor vehicle *(e.g. car, bus, but not a train)*:
   - during your work? about hours per week
   - during commuting? about hours per week
   - in your leisure time? about hours per week

   (if not applicable, please write '0')

2. How often did you engage in sports or strenuous exercise in your leisure time during the past four months which lasted long enough to perspire?

   not 1
   less than once a month 2
   about once a month 3
   about 2 - 3 times per month 4
   about 1 - 2 times per week 5
   3 or more times per week 6

3. Did you do physically strenuous sports during the past 12 months? yes 1 no 2

   If yes:
   - do you participate in a competition? yes 1 no 2
   - how many hours per week on average? hours per week
   - how many months per year? months per jaar
   - how many years? years
   - which sport(s)?

   (if you participate in several sports, please indicate which you perform most intensely)

1 athletics	8 fitness/aerobics	15 motorsports	22 surfing	29 walking
2 badminton	9 golf	16 hang-gliding	23 table tennis	30 water sports
3 basketball	10 handball	17 rowing	24 tennis	31 cycling
4 mountaineer	11 hockey	18 skating	25 gymnastics	32 sailing
5 bowling	12 horse riding	19 shooting	26 boxing/fencing	33 swimming
6 dance/ballet	13 weight training	20 skiing	27 volleyball	34 other:.
7 biking	14 rugby	21 squash	28 (indoor)football	....

.....

4. Did you have a sports injury during the past 12 months which forced you to stop training or competition or prevented you from playing the next time? yes 1 no 2

   If yes: which bodily region? *(if you had several injuries, please indicate the most severe injury)*

1 neck	1 shoulders	1 hips/thigh	1 head	1 groin
1 upper back	1 elbows	1 knees	1 arms	1 legs
1 lower back	1 wrists/hands	1 ankles/feet	1 belly	

5. Did you have sick leave caused by a sports injury during the past 12 months? yes 1 no 2

   If yes:– how many working days? days

6. Have you been treated medically for a sport injury during the past 12 months? yes 1 no 2

Low back pain (1)

Complete these questions only if you had low back pain during the past 12 months.

1. Please indicate your age when you experienced your low back pain for the first time:My age was: ? ? year

2. What caused your low back pain:

– a sports injury?	yes 1	no 2
– an accident?	yes 1	no 2
– a sudden movement?	yes 1	no 2
– the lifting of a heavy load?	yes 1	no 2
– a bad posture during a long period?	yes 1	no 2
– stress?	yes 1	no 2
– the climate (draught, coldness, moisture)?	yes 1	no 2
(only for females):		
– a pregnancy, delivery	yes 1	no 2
– menstruation?	yes 1	no 2

3.

– Is your low back pain associated with your work?	yes 1	no 2
– is your low back pain associated with leisure time activities?	yes 1	no 2
– Did your low back pain start during your current work?	yes 1	no 2

4. How often have you had separate spells of low back pain during the past 12 months?

once	1
between 2-4 times	2
between 5-10 times	3
more than 10 times	4
my complaints are always there	5

5. How many days were you on sick leave during the past 12 months due to your low back pain?

none	1
1-7 days	2
8-14 days	3
15-28 days	4
between 1-3 months	5
longer than 3 months	6

6. How long was the longest spell of your low back pain during the past 12 months?

less than one day	1
1-7 days	2
1-4 weeks	3
5-7 weeks	4
between 8 weeks and 3 months	5
3-12 months	5

7. Did you have radiating low back pain (to the legs) during the past 12 months to:

– the left and/or right knee?	yes 1	no 2
– the left and/or right ankle/foot?	yes 1	no 2

Low back pain (2)

Complete these questions only if you had low back pain during the past 12 months.

8. Please describe the last period of your low back pain

cured completely within a few days	1
cured completely, but it took a few weeks	2
cured not entirely, sometimes my symptoms do recur	3
not cured, my symptoms persisted	4
not cured, but my symptoms started only recently	5

9.

– Is your low back pain getting worse?	yes	1	no	2
– Is the severity of your low back pain varying widely?	yes	1	no	2
– Did your low back pain start suddenly?	yes	1	no	2
– Does your low back pain hinder your sleep?	yes	1	no	2
– Does your low back pain persist during holidays?	yes	1	no	2
– Are you getting up in the morning with a stiff feeling in your lower back?	yes	1	no	2
– Do you have a numb, dead or tingling feeling in the legs when you have to sneeze, cough or strain?	yes	1	no	2

10. Did you ever had:

– lumbago?	yes	1	no	2
– a herniated (slipped) lumbar disc?	yes	1	no	2
– a medical treatment due to your low back pain?	yes	1	no	2
– a hospitalisation due to your low back pain?	yes	1	no	2

11. How many times during the past 12 months did your low back pain cause you to:

– consult a physician	yes	1	no	2
– consult a physiotherapist, chiropractor or ostepath?	yes	1	no	2

12. Is your low back pain causing trouble when:

	I do this never	no trouble	little trouble	much trouble
standing for a long period	1	2	3	4
sitting for a long period	1	2	3	4
moving loads (more than 5 kg)	1	2	3	4
moving heavy loads (more than 20 kg)	1	2	3	4
performing jobs which require exertion of arms/hands	1	2	3	4
working with vibrating tools	1	2	3	4
driving in vehicles	1	2	3	4
working in uncomfortable postures	1	2	3	4
working in the same postures for a long period	1	2	3	4

13.

– Are you partly disabled due to your low back pain?	yes	1	no	2
– Did you change your work in the past due to your low back pain?	yes	1	no	2
– Are your workplace, tools or working hours adjusted due to your low back pain?	yes	1	no	2

Neck and/or shoulder pain (1)

Complete these questions only if you had neck and/or shoulder pain <u>during the past 12 months</u>.

14. Please indicate your age when you experienced your neck and/or shoulder pain for the first time — My age was: ? ? year

15. What caused your neck and/or shoulder pain:

– a sports injury?	yes 1	no 2
– an accident?	yes 1	no 2
– a sudden movement?	yes 1	no 2
– the lifting of a heavy load?	yes 1	no 2
– a bad posture during a long period?	yes 1	no 2
– stress?	yes 1	no 2
– the climate (draught, coldness, moisture)?	yes 1	no 2
(only for females):		
– a pregnancy, delivery	yes 1	no 2

16.

– Is your neck and/or shoulder pain associated with your work?	yes 1	no 2
– Is your neck and/or shoulder pain associated with leisure time activities?	yes 1	no 2
– Did your neck and/or shoulder pain start during your current job?	yes 1	no 2

17. How often have you had separate spells of neck and/or shoulder pain <u>during the past 12 months</u>?

- once 1
- between 2-4 times 2
- between 5-10 times 3
- more than 10 times 4
- my complaints are always there 5

18. How many days were you on sick leave <u>during the past 12 months</u> due to your neck and/or shoulder pain?

- none 1
- 1-7 days 2
- 8-14 days 3
- 15-28 days 4
- between 1-3 months 5
- longer than 3 months 6

19. How long was the longest spell of your neck and/or shoulder pain <u>during the past 12 months</u>?

- less than one day 1
- 1-7 days 2
- 1-4 weeks 3
- 5-7 weeks 4
- between 8 weeks and 3 months 5
- 3-12 months 6

20. Did you have radiating neck and/or shoulder pain (to the arms) during the past 12 months to:

– the left and/or right upper arm/elbow?	yes 1	no 2
– the left and/or right forearm/wrist/hand?	yes 1	no 2

Neck and/or shoulder pain (2)

Complete these questions only if you had neck and/or shoulder pain <u>during the past 12 months</u>.

21. Please describe the last period of your neck and/or shoulder pain

cured completely within a few days	1
cured completely, but it took a few weeks	2
cured not entirely, sometimes my symptoms do recur	3
not cured, my symptoms stayed	4
not cured, but my symptoms started only recently	5

22.

– Is your neck and/or shoulder pain getting worse?	yes	1	no	2
– Is the severity of your neck and/or shoulder pain strongly varying?	yes	1	no	2
– Did tour neck and/or shoulder pain start suddenly?	yes	1	no	2
– Does your neck and/or shoulder pain hinder your sleep?	yes	1	no	2
– Does your neck and/or shoulder pain persist during holidays?	yes	1	no	2
– Are you getting up in the morning with a stiff feeling in your neck or shoulders?	yes	1	no	2
– Do you have a deaf, dead or twinkling feeling in your arms or hands?	yes	1	no	2
– Does your neck and/or shoulder pain radiate into the arms when you have to sneeze, cough or squeeze?	yes	1	no	2

23. Did you ever had:

– a frozen shoulder?	yes	1	no	2
– a herniated cervical disc?	yes	1	no	2
– a medical treatment due to your neck and/or shoulder pain?	yes	1	no	2
– a hospitalisation due to your neck and/or shoulder pain?	yes	1	no	2

24. How many times during the past 12 months did you due to your neck and/or shoulder pain:

– consult a physician	yes	1	no	2
– consult a physiotherapist, chiropractor or osteopath?	yes	1	no	2

25. Is your neck and/or shoulder pain causing trouble when:

	I do this never	no trouble	little trouble	much trouble
standing for a long period	1	2	3	4
sitting for a long period	1	2	3	4
moving loads (more than 5 kg)	1	2	3	4
moving heavy loads (more than 20 kg)	1	2	3	4
performing jobs which require exertion of arms/hands	1	2	3	4
working with vibrating tools	1	2	3	4
driving in vehicles	1	2	3	4
working in uncomfortable postures	1	2	3	4
working in the same postures for a long period	1	2	3	4
making repetitive movements with arms or hands	1	2	3	4

Your own opinion (1)

Down beneath you can indicate which tasks cause symptoms. You are also invited to suggest how to improve these tasks.

1. Please indicate which jobs are heavy for the **low back** and ways to improve those jobs.

heavy tasks for the low back:	**how to improve:**
task 1. ____	task 1. ____
task 2. ____	task 2. ____
task 3. ____	task 3. ____

2. Please indicate which jobs are heavy for the **neck and/or shoulders** and ways to improve those jobs

heavy tasks for the neck/shoulders:	**how to improve:**
task 1. ____	task 1. ____
task 2. ____	task 2. ____
task 3. ____	task 3. ____

3. Please indicate which jobs are heavy for the **arms (elbows, wrists, hands)** and ways to improve those jobs

heavy tasks for the arms:	**how to improve:**
task 1. ____	task 1. ____
task 2. ____	task 2. ____
task 3. ____	task 3. ____

4. Please indicate which jobs are heavy for the **knees** and ways to improve those jobs

heavy tasks for the knees:	**how to improve:**
task 1. ____	task 1. ____
task 2. ____	task 2. ____
task 3. ____	task 3. ____

Your own opinion (2)

Down beneath you can indicate which tasks cause symptoms. You are also invited to suggest how to improve these tasks.

5. Every job has its 'heavy tasks'. Please indicate below which heavy tasks you have in your work and how to improve them.

heavy or uncomfortable task:	**how to improve:**
task 1.	task 1.
task 2.	task 2.
task 3.	task 3.

6. In many jobs, there are some very heavy tasks which are not conspicuous because the task is seldomly performed or takes a very short period of time. If there are such tasks in your work, please name them below and indicate how to improve them.

kind of work:	**how to improve:**
task 1.	task 1.
task 2.	task 2.
task 3.	task 3.

If you use tools which are not suitable for your job, please indiacte which tools and how to improve them.

unsuitable tools:	**how to improve:**
1.	1.
2.	2.
3.	3.

If you have health complaints related to your work which have not been addressed so far, please name them below and indicate to which tasks they are related.

health complaint:	**related to:**

Appendix D: Sample Form of CMDQ

The diagram below shows the approximate position of the body parts referred to in the questionnaire. Please answer by marking the appropriate box.

Body part		During the last work week how often did you experience ache, pain, discomfort in:					If you experienced ache, pain, discomfort, how uncomfortable was this?			If you experienced ache, pain, discomfort, did this interfere with your ability to work?		
		Never	1-2 times last week	3-4 times last week	Once every day	Several times every day	Slightly uncomfortable	Moderately uncomfortable	Very uncomfortable	Not at all	Slightly interfered	Substantially interfered
Neck		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Shoulder	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Upper Back		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Upper Arm	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lower Back		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Forearm	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Wrist	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Hip/Buttocks		☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Thigh	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Knee	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Lower Leg	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
Foot	(Right)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐
	(Left)	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐	☐

Appendix E: Sample Sheet of Body Part Discomfort Map

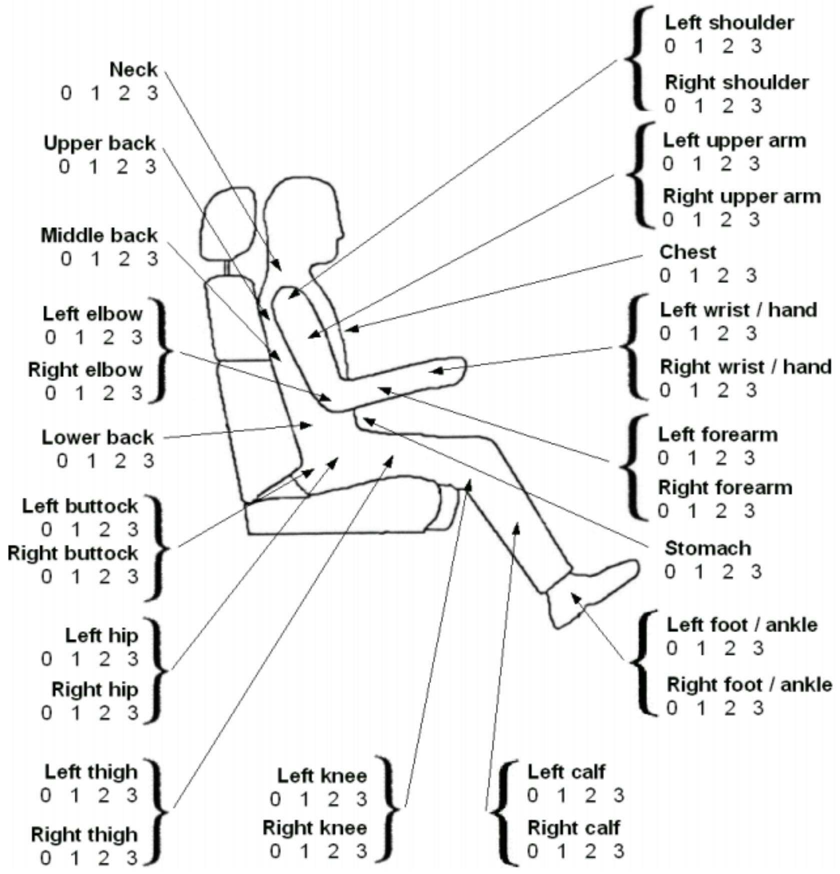
Body part discomfort map

In a **typical week** do you experience any **discomfort** in the main car that you drive? Use the scale below. Please circle the appropriate number.

0 No discomfort

1 Slight discomfort

2 Moderate discomfort

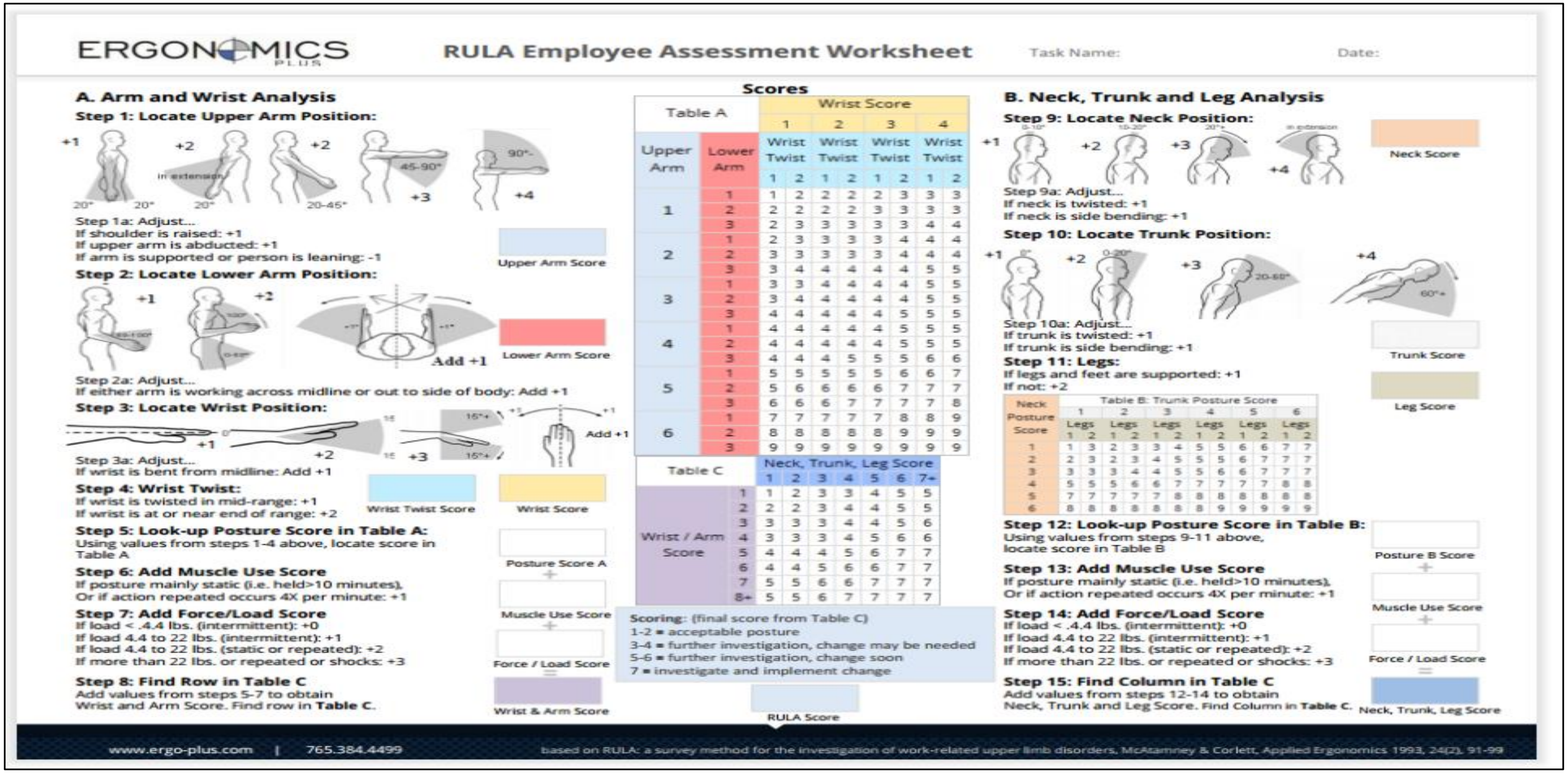


What do you believe are the **reasons** for any of this discomfort (including anything at work or elsewhere)?

____

____

Appendix F: Sample Worksheet of RULA, REBA and WERA



ERGONOMICS PLUS

RULA Employee Assessment Worksheet

Task Name:

Date:

A. Arm and Wrist Analysis

Step 1: Locate Upper Arm Position:

+1 (20° / 20°), +2 (20° in extension), +2 (20-45°), +3 (45-90°), +4 (90°+)

Step 1a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 2: Locate Lower Arm Position:

+1 (60-100°), +2 (0-60°, 100°+), Add +1

Lower Arm Score

Step 2a: Adjust...
If either arm is working across midline or out to side of body: Add +1

Step 3: Locate Wrist Position:

+1 (0°), +2 (15°), +3 (15°+), +1, Add +1

Step 3a: Adjust...
If wrist is bent from midline: Add +1

Step 4: Wrist Twist:
If wrist is twisted in mid-range: +1
If wrist is at or near end of range: +2

Wrist Twist Score

Wrist Score

Step 5: Look-up Posture Score in Table A:
Using values from steps 1-4 above, locate score in Table A

Posture Score A

+

Step 6: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

+

Step 7: Add Force/Load Score
If load < 4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Force / Load Score

=

Step 8: Find Row in Table C
Add values from steps 5-7 to obtain
Wrist and Arm Score. Find row in **Table C**.

Wrist & Arm Score

Scores

Table A		Wrist Score 1		Wrist Score 2		Wrist Score 3		Wrist Score 4	
Upper Arm	Lower Arm	Wrist Twist 1	Wrist Twist 2	Wrist Twist 1	Wrist Twist 2	Wrist Twist 1	Wrist Twist 2	Wrist Twist 1	Wrist Twist 2
1	1	1	2	2	2	2	3	3	3
	2	2	2	2	2	3	3	3	3
	3	2	3	3	3	3	3	4	4
2	1	2	3	3	3	3	4	4	4
	2	3	3	3	3	3	4	4	4
	3	3	4	4	4	4	4	5	5
3	1	3	3	4	4	4	4	5	5
	2	3	4	4	4	4	4	5	5
	3	4	4	4	4	4	5	5	5
4	1	4	4	4	4	4	5	5	5
	2	4	4	4	4	4	5	5	5
	3	4	4	4	5	5	5	6	6
5	1	5	5	5	5	5	6	6	7
	2	5	6	6	6	6	7	7	7
	3	6	6	6	7	7	7	7	8
6	1	7	7	7	7	7	8	8	9
	2	8	8	8	8	8	9	9	9
	3	9	9	9	9	9	9	9	9

Table C		Neck, Trunk, Leg Score 1	2	3	4	5	6	7+
Wrist / Arm Score	1	1	2	3	3	4	5	5
	2	2	2	3	4	4	5	5
	3	3	3	3	4	4	5	6
	4	3	3	3	4	5	6	6
	5	4	4	4	5	6	7	7
	6	4	4	5	6	6	7	7
	7	5	5	6	6	7	7	7
	8+	5	5	6	7	7	7	7

Scoring: (final score from Table C)
1-2 = acceptable posture
3-4 = further investigation, change may be needed
5-6 = further investigation, change soon
7 = investigate and implement change

RULA Score

B. Neck, Trunk and Leg Analysis

Step 9: Locate Neck Position:

+1 (0-10°), +2 (10-20°), +3 (20°+), +4 (in extension)

Neck Score

Step 9a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 10: Locate Trunk Position:

+1 (0°), +2 (0-20°), +3 (20-60°), +4 (60°+)

Step 10a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Trunk Score

Step 11: Legs:
If legs and feet are supported: +1
If not: +2

Leg Score

Neck Posture Score	Table B: Trunk Posture Score 1		2		3		4		5		6	
	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2	Legs 1	Legs 2
1	1	3	2	3	3	4	5	5	6	6	7	7
2	2	3	2	3	4	5	5	5	6	7	7	7
3	3	3	3	4	4	5	5	6	6	7	7	7
4	5	5	5	6	6	7	7	7	7	7	8	8
5	7	7	7	7	7	8	8	8	8	8	8	8
6	8	8	8	8	8	8	8	9	9	9	9	9

Step 12: Look-up Posture Score in Table B:
Using values from steps 9-11 above,
locate score in Table B

Posture B Score

+

Step 13: Add Muscle Use Score
If posture mainly static (i.e. held>10 minutes),
Or if action repeated occurs 4X per minute: +1

Muscle Use Score

+

Step 14: Add Force/Load Score
If load < 4.4 lbs. (intermittent): +0
If load 4.4 to 22 lbs. (intermittent): +1
If load 4.4 to 22 lbs. (static or repeated): +2
If more than 22 lbs. or repeated or shocks: +3

Force / Load Score

=

Step 15: Find Column in Table C
Add values from steps 12-14 to obtain
Neck, Trunk and Leg Score. Find Column in **Table C**.

Neck, Trunk, Leg Score

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based on RULA: a survey method for the investigation of work-related upper limb disorders, McAtamney & Corlett, Applied Ergonomics 1993, 24(2), 91-99

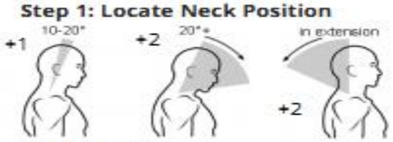
ERGONOMICS PLUS

REBA Employee Assessment Worksheet

Task Name: Date:

A. Neck, Trunk and Leg Analysis

Step 1: Locate Neck Position



Neck Score

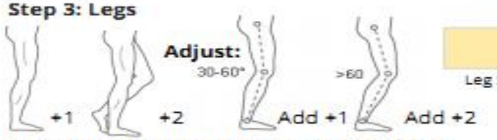
Step 1a: Adjust...
If neck is twisted: +1
If neck is side bending: +1

Step 2: Locate Trunk Position

Trunk Score

Step 2a: Adjust...
If trunk is twisted: +1
If trunk is side bending: +1

Step 3: Legs



Leg Score

Step 4: Look-up Posture Score in Table A

Using values from steps 1-3 above,
Locate score in Table A

Posture Score A
+

Step 5: Add Force/Load Score

If load < 11 lbs. : +0
If load 11 to 22 lbs. : +1
If load > 22 lbs.: +2
Adjust: If shock or rapid build up of force: add +1

Force / Load Score
=

Step 6: Score A, Find Row in Table C

Add values from steps 4 & 5 to obtain Score A.
Find Row in **Table C**.

Score A

Scoring
1 = Negligible Risk
2-3 = Low Risk. Change may be needed.
4-7 = Medium Risk. Further Investigate. Change Soon.
8-10 = High Risk. Investigate and Implement Change
11+ = Very High Risk. Implement Change

Scores

Table A		Neck 1				Neck 2				Neck 3			
	Legs	1	2	3	4	1	2	3	4	1	2	3	4
Trunk Posture Score	1	1	2	3	4	1	2	3	4	3	3	5	6
	2	2	3	4	5	3	4	5	6	4	5	6	7
	3	2	4	5	6	4	5	6	7	5	6	7	8
	4	3	5	6	7	5	6	7	8	6	7	8	9
	5	4	6	7	8	6	7	8	9	7	8	9	9

Table B		Lower Arm 1			Lower Arm 2		
	Wrist	1	2	3	1	2	3
Upper Arm Score	1	1	2	2	1	2	3
	2	1	2	3	2	3	4
	3	3	4	5	4	5	5
	4	4	5	5	5	6	7
	5	6	7	8	7	8	8
	6	7	8	8	8	9	9

Table C	Score B											
Score A	1	2	3	4	5	6	7	8	9	10	11	12
1	1	1	1	2	3	3	4	5	6	7	7	7
2	1	2	2	3	4	4	5	6	6	7	7	8
3	2	3	3	3	4	5	6	7	7	8	8	8
4	3	4	4	4	5	6	7	8	8	9	9	9
5	4	4	4	5	6	7	8	8	9	9	9	9
6	6	6	6	7	8	8	9	9	10	10	10	10
7	7	7	7	8	9	9	9	10	10	11	11	11
8	8	8	8	9	10	10	10	10	10	11	11	11
9	9	9	9	10	10	10	11	11	11	12	12	12
10	10	10	10	11	11	11	11	12	12	12	12	12
11	11	11	11	11	12	12	12	12	12	12	12	12
12	12	12	12	12	12	12	12	12	12	12	12	12

Table C Score + Activity Score = REBA Score

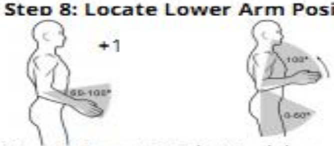
B. Arm and Wrist Analysis

Step 7: Locate Upper Arm Position:

Step 7a: Adjust...
If shoulder is raised: +1
If upper arm is abducted: +1
If arm is supported or person is leaning: -1

Upper Arm Score

Step 8: Locate Lower Arm Position:



Lower Arm Score

Step 9: Locate Wrist Position:

Wrist Score

Step 9a: Adjust...
If wrist is bent from midline or twisted : Add +1

Step 10: Look-up Posture Score in Table B

Using values from steps 7-9 above, locate score in Table B

Posture Score B
+

Step 11: Add Coupling Score

Well fitting Handle and mid rang power grip, ***good: +0***
Acceptable but not ideal hand hold or coupling acceptable with another body part, ***fair: +1***
Hand hold not acceptable but possible, ***poor: +2***
No handles, awkward, unsafe with any body part, ***Unacceptable: +3***

Coupling Score
=

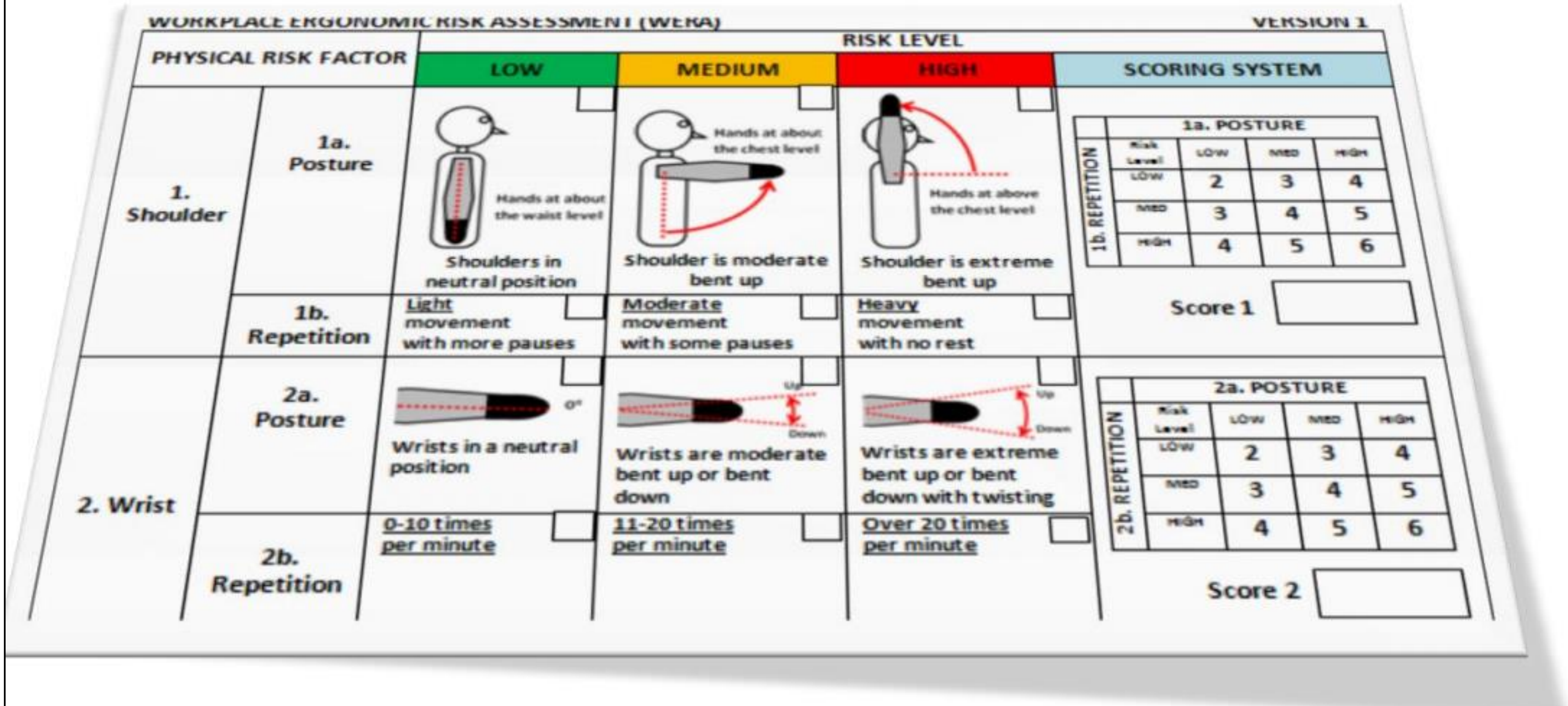
Step 12: Score B, Find Column in Table C

Add values from steps 10 &11 to obtain Score B. Find column in **Table C** and match with Score A in row from step 6 to obtain Table C Score.

Score B

Step 13: Activity Score

+1 1 or more body parts are held for longer than 1 minute (static)
+1 Repeated small range actions (more than 4x per minute)
+1 Action causes rapid large range changes in postures or unstable base



WORKPLACE ERGONOMIC RISK ASSESSMENT (WERA) VERSION 1

PHYSICAL RISK FACTOR		RISK LEVEL: LOW	RISK LEVEL: MEDIUM	RISK LEVEL: HIGH	SCORING SYSTEM
1. Shoulder	1a. Posture	Hands at about the waist level Shoulders in neutral position	Hands at about the chest level Shoulder is moderate bent up	Hands at above the chest level Shoulder is extreme bent up	1a. POSTURE (see table below)
	1b. Repetition	Light movement with more pauses	Moderate movement with some pauses	Heavy movement with no rest	Score 1
2. Wrist	2a. Posture	0° Wrists in a neutral position	Up / Down Wrists are moderate bent up or bent down	Up / Down Wrists are extreme bent up or bent down with twisting	2a. POSTURE (see table below)
	2b. Repetition	0-10 times per minute	11-20 times per minute	Over 20 times per minute	Score 2

1a. POSTURE

1b. REPETITION (Risk Level)	LOW	MED	HIGH
LOW	2	3	4
MED	3	4	5
HIGH	4	5	6

Score 1

2a. POSTURE

2b. REPETITION (Risk Level)	LOW	MED	HIGH
LOW	2	3	4
MED	3	4	5
HIGH	4	5	6

Score 2