Assessing Workers' Ability to Recognize Lifting Risk Factors for Low Back Pain: Investigating the Efficacy of a Simple Educational Message.

by

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Author's Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

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Abstract

Introduction: Participatory ergonomic approaches have been shown to be an effective method for identifying work place hazards. Since in many workplaces, expertise in ergonomics is not available, simple educational messages to identify low back injury (LBI) hazards were developed. This thesis examined lifting risk perceptions of workers and the efficacy of a simple educational message on improving their ability to recognize key LBI hazards, in particular, lifting objects on or close to the ground.

Methods: 178 participants from differing sectors were shown 44 different lifting videos (representing 36 lifting scenarios). These scenarios differed in terms of factors such as lifting height origin/destination, weight, and the amount of horizontal reach. Participants were asked to rate each video, from 0-10, on how likely they believed the lifting task they just saw could eventually lead to a low back injury. One of two educational messages was then shown to the participants. These messages were crafted with the help of academic experts and knowledge translation professionals in health and safety associations. One message was used as the intervention and spoke of the risk of lifting objects from close to the floor and the other as the control and spoke of the use of back belts in industry. After reading the message, participants were shown and asked to rate the same 44 lifting videos again, but in a different order. Participant's ratings of risk were correlated to a biomechanically-based tool (3DMatch) that estimates low back loading.

Results: As lifts deviated from a waist-to-waist height, light object lift (mean Likert score = 0.421 units), ratings of risk perception increased. The highest rated tasks were the floor-to-waist stoop lift, heavy floor-to-floor lift, and the heavy floor-to-waist lift (mean Likert scores = 7.73, 7.382, and 7.107 respectively). Pre-post score differences were used to assess message efficacy. Of the 36 types of tasks, 19 significantly changed in the Lifting Height Message receiving group compared to 3 in the Back Belt Message group. The 19 changes were mainly seen in the videos that had lift origins at floor height. Participant' risk ratings correlated positively, albeit only moderately with 3DMatch (R-value = 0.495, $p<0.05$). Demographically stratified correlations were also positive but were weak to moderate in strength (R-value range = 0.357 to 0.674, $p<0.05$).

Conclusion: The results support the use of a simple message to increase conceptual awareness of the important lifting hazard of lifting objects from near the ground. This increase in recognition is the first step in the injury prevention cycle of identifying hazards, assessing risks, and controlling hazards.

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For my parents...

Your love, prayers, and support have helped me become who I am today.

Please know that I will always be striving to make you ever proud of me.

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1. Introduction

Musculoskeletal disorders (MSDs) and injuries in the workplace can affect worker quality of life, as well as worker production and quality of work. MSDs also cause employers to suffer from both direct and indirect financial costs. Some indirect costs include overtime, modification of equipment, administration fees, retraining and lost time in productivity. Although costs have been decreasing since 2009, government benefit payments still totalled to $2.7 billion in 2012 (compared to $3.2 billion in 2009) in Ontario (WSIB, 2012, 2013). These costs do not include those of arranging modified work or replacing and training workers for companies. For society as a whole, these injuries involve added burden on public health services. Of course, their effects on the injured workers are considerable including loss of income, disability as well as pain and suffering. From 2003 until 2012, Ontario's Workplace Safety and Insurance Board (WSIB) statistical report shows that injuries of the low back consistently account for approximately 20% of all lost time claims (WSIB, 2013). The next body parts with the highest incidence of injuries are the fingers and legs, each accounting for 9% of lost time claims (WSIB, 2013). In terms of injury type, overexertion, which includes tasks where workers work beyond their physical capabilities in terms of load weight, repetitive motion and awkward postures, accounted for 19% of leading injury events (WSIB, 2013). Although overexertion injuries have since decreased from 23% in 2003, more work needs to be done in establishing the efficacy of current workplace MSD risk assessment and intervention practices to help solve this MSD problem (Wells, 2009).

1.1 Small Businesses and MSDs

Like all enterprises, small business workers also suffer from MSDs. Small businesses can be defined as workplaces that have fewer than 20 employees (Ontario, 2007). In 2012, smaller businesses, with less than 99 workers, employed 69.7% of the total private labour force (7.7 million individuals) (Canada, 2013). These businesses can include workplaces like small bakeries, convenience stores and construction companies. Although these workplaces differ in terms of sector, they all require some form of manual materials handling (MMH). Since the Canadian government has allowed these small businesses various exemptions from certain occupation health and safety (OHS) regulations (such as not needing to have a health and safety committee), these MMH tasks can lead to MSDs (MacEachen et al., 2010). The exemptions exist due to most small businesses not having the means to establish their own OHS department or to hire specialists. Therefore, assistance in tackling these MSD issues may lie with third parties such as the various health and safety associations (HSAs) that exist to help provide the small businesses with the necessary resources and knowledge to address their OHS needs in general and ergonomic needs in particular (MacEachen et al., 2010).

In order to prevent injury, hazards must be identified, associated risks assessed and those hazards controlled. Given the large number of small companies, it is unrealistic to expect that they can acquire help directly from outside agencies. The challenge is therefore to provide information and skills so that these individuals and organizations can do it themselves. This is especially true for low back pain (LBP) hazards. Ergonomics is often thought to be "too complicated" so the challenge is to provide simple tools to allow small companies to recognize and take steps to control these LBP hazards.

There are two challenges here: recognizing LBP hazards and developing a control. This thesis addresses the first challenge of recognizing LBP hazards.

1.2 Purpose

The purpose of this research was to:

- Determine which lifting risk factors people perceive to be risky
- Investigate the efficacy of using simple educational messages to affect awareness and risk perception of a key LBP hazard
- Assess and correlate the risk assessment abilities of workers from various demographic backgrounds to an industrially used risk assessment tool

1.3 Hypotheses

The hypotheses of this investigation are as follows:

1. *Significant differences of perceived risk ratings will be seen for the various lifting risk factors.*

    1.1 Vertical Height – Low lying lifts will have higher video rating scores than the more upright standing lifts.

    Studies investigating lifting height as a risk factor for low back pain have shown that the lower the region that a lift begins from, the higher the compression and shear experienced by the spine and thus, the higher the risk of suffering a low back injury(Allread, Marras, Granata, Davis, & Jorgensen, 1996; S Lavender, Andersson, Schipplein, & Fuentes, 2003; Marras, Granata, & Davis, 1999; Plamondon, Larivière, Delisle, Denis, & Gagnon, 2012).

1.2 Lifting Vs. Lowering – There will be no difference in video rating scores between lifting and lowering.

In this study, all lowering tasks will be controlled, meaning objects will not be dropped. This will make it so lowering will be an eccentric version of a lift. Studies investigating the effects of lifting vs. lowering are unclear in determining which task is riskier, therefore they will be perceived to be equally risky.

1.3 Asymmetry – Videos that have a twisting component will be rated higher than purely sagittal lifts.

Many studies show that introducing an asymmetric component to a lift increases spinal compression and low back moments.

1.4 Coupling – Videos that have an object that provides poor coupling will be rated higher than equivalent lifts of objects with good coupling.

Studies looking into the effects of coupling on low back loading have shown that, biomechanically, good coupling helps decrease low back compression and shear.

1.5 Frequency – Videos that have repetitive tasks will be rated higher than the equivalent single lift videos.

Evidence in the literature shows that although peak low back loads of repetitive lifting tasks are similar to those of single instance lifts, the cumulative nature of the forces experienced by the spine can increase the risk of a low back injury.

1.6 Horizontal Reach – Videos where lifters are required to reach will be rated higher than lifts that are near.

Studies examining the effects of horizontal reach have found that increasing the reach distance of a lift increases trunk kinematics, spinal compression, spinal shear and, in consequence, low back disorder risk especially when coupled with lifting nearer the floor.

1.7 Lifting Technique – Videos where the lifter uses a stoop lift technique will be rated higher than the squat lift equivalent lifts.

Studies showed that although there are positive and negative aspects to either squat lifting or stoop lifting, it is seen that, biomechanically, stoop lifting was worse in terms of lumbar shear, lumbar passive tissues and lumbar discomfort.

1.8 Weight of Object – Videos that have heavier objects will receive higher ratings of perceived risk than the medium and light weighted objects.

Load has been shown to be a significant lifting risk factor for low back injury.

1.9 Use of Back Belt – Videos where the subject is wearing a back belt will have higher ratings than the non-back belt wearing equivalent video.

The evidence in the literature is not entirely clear as to whether wearing a back belt is protective or risky. However, biomechanically, since wearing a back belt has been shown to increase intra-abdominal pressure, which in turn increases spinal stability through increased spinal compression, and in accordance with the second educational message of this thesis, back belts will be hypothesized as being riskier.

2. *The educational message will increase video rating scores of low-lying lift videos post-educational message.*

Studies investigating participatory ergonomic training and education can have an effect on raising awareness. The increase in scores will denote participants regarding the tasks as having a higher chance of causing low back pain.

3. *Influences on video rating correlations by demographic factors like work experience and familiarity in the field of ergonomics will be observed.*

Studies investigating ability to assess posture is affected by ergonomic experience. Therefore, video ratings will be a function of the type and amount of ergonomic experience that they have.

2. Review of Relevant Literature

2.1 Overview of Risk Factors for LBP

Of studies done with adults in general working populations, epidemiological studies have shown that individual factors such as sex, age, BMI, and even trunk length can have a significant impact on risk of developing LBP. Women have been shown to have higher incidence rates of developing LBP compared to men (Andersson, 1999; Hoy, Brooks, Blyth, & Buchbinder, 2010). Additionally, people in their third decade of life tend to have the highest incidence rates of LBP and the prevalence of LBP tends to increase until approximately 65 years of age and then drops off (Andersson, 1999; Hoy et al., 2010). As well, higher BMI's have been shown to increase spinal loading during work tasks and therefore, increase risk (M. Adams, Mannion, & Dolan, 1999; Andersson, 1999; Hoy et al., 2010). Longer backs or torsos tend to increase the moment arm about the L4/L5 vertebrae and thus increase the amount of muscle activity which in turn further loads the spine and therefore, also increases risk (M. Adams et al., 1999).

Biomechanical studies have linked work exposures and anatomical considerations to risk of developing LBP. Two longitudinal studies looking at associations between physical loading and LBP found that the jobs with the highest rates of reporting lost time due to a low back injury consisted of tasks that included prolonged standing, awkward posture and/or awkward lifts (Sterud & Tynes, 2013; van Oostrom, Verschuren, de Vet, Boshuizen, & Picavet, 2012). Further studies investigating posture and force on the occurrence of LBP report odds ratios of 1.1-2.0 and 1.4-2.1, respectively and that loading of the spine during a flexed posture would significantly affect intervertebral disc height loss and cause an increase injury risk (Gooyers, McMillan, Howarth, & Callaghan, 2012; Griffith et al., 2012). A study done by Hoogendoorn et al. found that lifting tasks requiring 60° of flexion for more than 5% of working time, 30° of trunk rotation for more than 10% of working time or lifting more than 25 kg more than 15 times in one day have relative risk values of 1.5, 1.3 and 1.6 respectively (Hoogendoorn et al., 2000). Studies using biomechanical models found that risk factors such as spinal compression and shear are important in evaluating LBP risk and provided more insight than measuring exposures like trunk kinematics or hand inputs or even measuring psychosocial factors (Kerr & Frank, 2001; R. Norman, Wells, & Neumann, 1998). And finally, a study done by Adams et al. found that the anatomical lumbar ranges of motion (reduced lumbar mobility or lordosis) were consistent predictors of first time incidence of serious LBP (M. Adams et al., 1999).

Overall, there is much epidemiological and biomechanical evidence showing that there are a multitude of physical risk factors that could lead to LBP. These factors are either related to the physical aspects of the individual or of the work task. Further research is required to help decrease these risk factors. This study was aimed at decreasing work task risk factors related to lifting and the flexed postures they can include.

2.2 The NIOSH Equation

The National Institute of Occupational Safety & Health (NIOSH) lifting equation is used to assess manual materials handling (MMH) tasks. In a survey done in 2005, it was found that every ergonomist uses some form of MMH analysis. The NIOSH lifting equation is an ergonomic tool which uses different variables to calculate risk of MMH tasks (Dempsey, McGorry, & Maynard, 2005). It was originally developed in 1981 and was revised in 1991 to include two additional lifting factors (USDHHS, 1981; Waters, Putz-Anderson, Garg, & Fine, 1993). Its intended use was to decrease overexertion injuries in the work place (USDHHS, 1981). It was created using criteria from the fields of biomechanics, psychophysics and work physiology; specifically, it is used to constrain lumbosacral stress, metabolic stress, and the workload based on a worker's perception of their own lifting capabilities (USDHHS, 1981; Waters et al., 1993). The equation consists of a horizontal, vertical, vertical distance, asymmetry, frequency, and coupling components; these components are multiplied together with given constants to produce a recommended weight limit (RWL) which acts as the denominator for the load weight that is being lifted to produce a lifting index value (LI) which can then be categorized into tasks that have nominal risk ($LI < 1.0$), increased/medium risk ($1.0 < LI < 3.0$), or greatly increased/high risk ($LI > 3.0$) (Elfeituri & Taboun, 2002; Waters, Baron, & Piacitelli, 1999).

The NIOSH equation has been well-established as a valid and effective tool to assess risk of developing LBP in MMH tasks. A cross-sectional study done by Waters et al. explored whether or not there existed a correlation between the LI score of a job and reported low back pain incidences and found jobs that had an LI between 2.0 and 3.0 produced an odds ratio of 2.45 (Waters et al., 1999). Although studies have shown a peak single task lifting index measure can be a better predictor of LBP than typical job LIs, LBP risk factors tend to show a dose-response relationship; therefore, the more recent literature that has been working to validate the NIOSH equation's ability to predict LBP have been using cumulative or composite scores like the cumulative lifting index score (CLI) or the peak composite lifting index score (PCLI) (Boda, Garg, & Campbell-Kyureghyan, 2012; Garg, Kapellusch, et al., 2014; Lu, Waters, Krieg, & Werren, 2013). CLI's above 2.0 were associated with jobs where a worker would be 5.1-6.5 times more likely to report LBP (Lu et al., 2013). Jobs with PCLI's of 2.0 or greater had hazard ratio (HR) estimates of 3.7-4.2 of developing LBP and HR estimates of 9.8-21.9 of seeking care for LBP (Garg, Kapellusch, et al., 2014; Garg, Kappelusch, et al., 2014). Given the strong relationship between the NIOSH equation LI (or CLI) and the incidence of LBP, it seems to be a valid and effective tool for risk assessment.

Each of the seven inputs of the 1991 NIOSH equation has a significant effect on LIs and the subsequent implications of risk. The vertical lifting height factor is related to three inputs: vertical origin, destination and distance. The optimal lifting vertical height is at approximately waist height and risk has been found to increase as lifts/lowers move into areas that are above or below this range (Russell, Winnemuller, Camp, & Johnson, 2007). Specifically for this study, past investigations have found that lifts originating closer to the ground create significantly higher compression forces and shear forces in the spine than higher origin lifts (Hoozemans, Kingma, de Vries, & van Dieën, 2008; Marras, Granata, et al., 1999). As the load weight factor increases, the amount of risk also increases. Studies in the literature have investigated lifting tasks and found that load weight has a significant effect on biomechanical, physiological and psychophysical aspects of lifting (Hoozemans et al., 2008; Marras et al., 1995). As the horizontal distance from the lifter to the object increases, the maximum moment experienced at the low back increases, therefore, increasing the risk. Horizontal distance has been shown to be a very strong and significant risk factor in MMH and as much as possible should be done to decrease the horizontal reach distance of any lift (Ferguson, Marras, & Burr, 2005; Potvin, 1997). Another input that has been shown to have a significant impact on risk is lifting frequency and duration. As the lifts required per minute/hour/day increase, the cumulative physical and physiological strain on the body increases (Elfeituri & Taboun, 2002; Marras et al., 1995). Lifting asymmetry is the measured angle between the sagittal plane of the lifter to the object being lifted. This asymmetry can also be referred to as twisting and as the angle from the sagittal plane increases, the amount of risk has been shown to increase significantly as well (Elfeituri & Taboun, 2002; Ferguson et al., 2005). Finally, coupling can be categorized as good, fair or poor and as coupling decreases in quality, the amount of risk increases. Biomechanical studies have shown that when handles are introduced to box lifting, spinal compression, shear and moments significantly decrease (K. Davis, Marras, & Waters, 1998; Marras, Granata, et al., 1999). However, a study done by Adams et al. investigated the effects of lifting a weighted milk crate with handles and a similarly weighted bag of dog food that lacked handles and found that the bag of dog food was easier to lift, both psychophysically and physiologically (K. Adams, 2010). Therefore, coupling seems to be a more complex input than initially thought and other factors like grip friction and comfort should also be considered when labelling lift coupling (K. Adams, 2010).

The revised NIOSH equation is but one of many MMH analysis tools and there are many studies investigating the effectiveness, reliability and sensitivity of the revised NIOSH equation compared to other tools. Along with the Snook tables and 1981 NIOSH equation, the effectiveness of the 1991 revised NIOSH equation was assessed (Marras, Fine, Ferguson, & Waters, 1999). Industrial tasks were categorized into low, medium and high risk groups. When all jobs were analyzed using the three methods, the comparison between them all showed that although the 1981 equation and psychophysical approach performed well at identifying low risk jobs (91% and 91%, respectively), both were not as sensitive in identifying the medium and high risk jobs and tended to err on the side of labelling a job as low risk when in fact it was not (Marras, Fine, et al., 1999). On the other hand, the 1991 NIOSH equation was best at identifying high risk jobs (73%) but could not identify low and medium risk jobs well (Marras, Fine, et al., 1999). The main difference is that the 1991 equation seems to be a more conservative approach compared to using the 1981 NIOSH equation and the psychophysical Snook Tables. The increased conservativeness of the revised NIOSH equation has been shown to come from its restrictive horizontal and lifting frequency multipliers (Elfeituri & Taboun, 2002). In the study done by Elfeitrui & Taboun, they showed that the average lifting weight accepted by all 13 of their participants was substantially higher than the RWL produced by the 1991 NIOSH equation (2.56 to 5.33 times higher depending on the lifting task) (Elfeituri & Taboun, 2002). Biologically, this will be relevant when workers start to assess work place demands, they may be stronger than the equation sets them out to be and may give lower-than-expected ratings to each task. Comparisons have also been done between the NIOSH equation and the functional capacity evaluation (FCE). One such study conducted by Kuijer et al. sought to find out if both tools produced similar recommended safe lifting weights for a floor to waist lifting task and found, yet again, that the NIOSH equation produced a lower safe lifting weight than the FCE (Kuijer et al., 2006). On average, the 1991 NIOSH equation RWL was lower than the FCE safe lifting weight limit by 15.0 kg for people returning to work (Kuijer et al., 2006). Another study done by Lavender et al. investigated the interrelationships and agreement rates of 5 commonly used MMH evaluation methods: NIOSH, 3 Dimensional Static Strength Prediction Program (3DSSPP), the Lumbar Motion Monitor model (LMM), and two variations of the United Auto Workers General Motors Ergonomic Risk Factor Checklist (one considering only the manual lifting score and one considering the manual lifting score combined with posture scores) (SA Lavender, Oleske, & Nicholson, 1999). Lavender et al. reported finding correlation values ranging from 0.20 to 0.80 and when looking at agreement of identifying priority/high risk jobs, it was concluded that there is limited agreement between the MMH evaluation methods (SA Lavender et al., 1999). This meant that a task could be considered acceptable when using one evaluation method and unacceptable using another. One explanation for the poor agreement is that each method could take into account different underlying causes of LBP (SA Lavender et al., 1999). This has implications in the understanding that identification of high risk tasks is dependent on the MMH evaluation method used (SA Lavender et al., 1999). Finally, Russell et al. compared the exposure indexes (EI) of 5 lifting analysis tools: NIOSH, American Conference of Governmental Industrial Hygienists Threshold Limit Value (ACGIH TLV), Snook tables, 3DSSPP and Washington Department of Labor and Industries Early Intervention (WA L&I EI) (Russell et al., 2007). Lifts of differing heights were examined and it was found that the NIOSH, ACGIH TLV and Snook methods garnered similar patterns of exposure (as lifting height increase, so did EI) (Russell et al., 2007). The WA L&I EI and 3DSSPP predicted significantly lower EI values than the other methods (up to 6 and 3.5 times lower, respectively) and both showed differing patterns in that the lowest height lifts produced higher EI values for both tools, while the highest height lifts produced higher EI values only for the WA L&I lifting calculation (Russell et al., 2007). Aside from weights, ease of use was also commented on. The ACGIH TLV, Snook and WA L&I EI methods were considerably simpler to use since they needed fewer inputs compared to the six required by the NIOSH equation (Russell et al., 2007). Alternatively, the NIOSH equation offers a greater range of interpretive capabilities which allow the assessor to find what aspects of the lift could be modified (Russell et al., 2007). In other words, the NIOSH equation seems to be the most conducive method for understanding the impact of inputs or how the changes of lift inputs have on lifting exposures.

Therefore, based on the evidence listed above, the NIOSH equation was used, in this study, as a model for creating videos of lifting instances that selectively differed in each of the various factors of the equation.

2.3 Effect of Lifting Height or Back Belts: The Development of Educational Messages

One intervention message was related to lifting height and its effect on low back pain risk factors. Lifting height origin has a significant effect on low back loading in that lifts originating from near or at the floor produce higher levels of spinal compression and shear (Davis & Marras, 2005; Hoozemans et al., 2008). Lifting from lower heights can lead to repetitively increased trunk flexion postures (postures greater than 60 degrees of flexion) which, over time, have been shown to lead to low back injuries like disc herniation (Callaghan & McGill, 2001; Hoogendoorn et al., 2000). Traditionally, load and horizontal distance were seen as the most impactful factors of determining spinal loads during a lift; however, there is strong evidence that lifting height should also be considered a strong factor in determining risk of low back injury (Ferguson et al., 2005; Marras, Granata, et al., 1999; Waters et al., 1993). Indeed, there has been evidence that when lifting a 12 kg weight, upper body segment mass could account for up to 70% of the spinal loading forces (Ekholm, Arborelius, & Nemeth, 1982). Furthermore, past studies have investigated increasing lifting loads from 7.5 to 27.3 kg and found that the spinal forces were better modulated by the load's position rather than simply by load (Hoozemans et al., 2008; Marras, Granata, et al., 1999).

The second message was related to using abdominal belts in manual materials handling tasks. Studies investigating abdominal belts have produced mixed evidence for encouraging and discouraging the use of the belts (McGill, 1993; Mcgill, 2007). The studies that showed positive side effects were psychophysical and biomechanical. Psychophysically, studies have demonstrated that workers who used the belts felt they could lift greater loads and, in fact, lifted greater loads when they performed lifting tasks with self-selected weights (Chen, 2003; Magnusson, Pope, & Hansson, 1996). Furthermore, there is biomechanical evidence that the belts restrict gross trunk range of motion, which is a possible factor in preventing low back injuries (Hashimoto et al., 2013). The studies that showed negative side effects were biomechanical and physiological. Biomechanically, abdominal belts increase intra-muscular pressure and intra-abdominal pressure during lifting tasks which, although increases spine stability, also increases spinal loads which increases the risk and possible severity of an injury (McGill, Norman, & Sharratt, 1990; McGill, 1993; Miyamoto, Iinuma, & Maeda, 1999). Physiologically, abdominal belts, when worn during exercise significantly increase blood pressure and heart rate which possibly puts the cardiovascular system at higher risk of pathologies like stroke (Hunter et al., 1989; Marley & Duggasani, 1996; Muir, 2013). Overall, if back belts are used, they should only be used temporarily given the uncertainty of benefits and possibility for harmful effects (Ammendolia, Kerr, & Bombardier, 2005).

The messages used in this study were crafted using the information gathered above and with the help of a team of researchers and collaborating health and safety associations. It was concluded that as origin lifting height decreases, the increase in risk of developing LBP increases. Additionally, although using abdominal belts aids individuals psychophysically, the belts should only be used temporarily for while wearing them, risk of a more severe injury or ailment increases.

2.4 Participatory Ergonomic Approaches and Using Workers in Task Analysis

Participatory ergonomics (PE) is an approach used by companies to help decrease and prevent MSDs. PE essentially allows for workers to actively participate in the analysis of and the subsequent planning and changing of their own workplace tasks (Wilson & Haines, 1997). The solutions developed by a PE approach exist at the individual (micro) as well as the organizational or systems level (macro) (Hignett, Wilson, & Morris, 2005). Likewise, PE can be used in a range of workplaces from small businesses to large industrial companies in industrialized or industrially developing countries (Zalk, 2001).

While establishing any ergonomic program, it is paramount to ensure that as many members of the workplace are aware of and participate in the process so that all perspectives will be heard and thus, change will more likely take place (R Wells, Norman, Frazer, & Laing, 2004). The people involved in a successful PE program can include employees ranging from workers to upper management and everything in between (Haines, Wilson, Vink, & Koningsveld, 2002). Workers, then, may be asked to help generate, evaluate and help implement solutions, as well as help identify problems, such as in this study. Furthermore, since workers are usually intimately familiar with work tasks, they may help the PE process by addressing topics to focus on to further enable prioritization of problems.

Workers have successfully been utilized to assess tasks for risks. Studies in various sectors have shown that involving workers in the process of analyzing tasks and identifying risk factors has positive outcomes in health and safety (Cole, Rivilis, Eerd, & Cullen, 2005; Rivilis et al., 2008). Studies investigating the use of a posture matching software tool have shown that amateurs (users with little to no ergonomic experience) can assess postures successfully when compared to experts given some time and training to help reduce errors in classification (Andrews et al., 2008; Weir et al., 2011). It should be noted that amateurs generally took only slightly less time to assess postures (2.12 seconds compared to 2.55 seconds for experts), but also produced a greater number of errors compared to experts (14% compared to 6%) (Andrews et al., 2008; Weir et al., 2011). Additionally, investigations comparing worker assessments with ergonomic specialist assessments when using a MSD risk factor questionnaire found workers and supervisors agreed with ergonomic specialists the majority of the time (up to 86% and 92% of the time for workers and supervisors, respectively) (Winnemuller, Spielholz, Daniell, & Kaufman, 2004). However, the percentage agreement of workers and supervisors with ergonomists varied between sectors of work.

Work done investigating the abilities of workers assessing risk have relied on having the workers use tools or checklists outlining task postures or risk factors to determine if a task would be considered low, medium or high risk. More research is required to see if simpler yet less tangible concepts can be successfully employed by workers in future risk assessment projects. To be effective, PE generally requires some form of training or education. Therefore, this study attempted to address whether an educational message was effective in helping workers to gauge risk in lifting tasks.

2.5 Measuring Knowledge Transfer and Utilization

Knowledge transfer can be measured by knowledge utilization. Knowledge can be used conceptually, instrumentally, or strategically (Kramer et al., 2013). Conceptual knowledge use can also be considered as "enlightenment", where the information learned affects the understanding of an issue (Kramer et al., 2013). Physically, this can be seen if workers talk about newly gained knowledge, if their attitudes change for the better on the topic, or if they illustrate they have the ability to make changes using their new knowledge. Instrumental knowledge use occurs when new policies or programs are developed using transferred knowledge (Kramer et al., 2013). Physically, this can be seen if actual changes have occurred, or if work tasks have changed. Lastly, strategic knowledge use occurs when gained knowledge is used politically (Kramer et al., 2013). This can mean to justify or support a decision or to use knowledge to raise awareness or to resolve existing issues. Based on the definitions of knowledge utilization, the educational messages in this study were meant to raise awareness and thus, participants used the knowledge in a conceptual way.

There are studies showing that immediate knowledge transfer outcomes can be significantly altered. A study testing the effects of preventative ergonomic training and the reduction of risk factors for cumulative trauma disorders in computer workers found that the ergonomic training program increased participant knowledge of correct computer equipment placement using a multiple choice question quiz (Rizzo & Pelletier, 1997). The improvement in knowledge led to observed ergonomic changes and improvement in participant comfort. Another study using an active ergonomic training program (the program included skill development in work station analysis, active participation and practice in implementing multiple prevention strategies i.e. increased engagement training) for computer users also found ergonomic knowledge increased using a multiple choice question quiz but also found increased self-efficacy which reduced risk factor exposures, decreased pain intensity, frequency and duration in participants (Greene, DeJoy, & Olejnik, 2005). Finally, a study looking at the effects of ergonomic training for teleworkers (workers who work from home or someplace other than work) found that participant scores of knowledge, attitude and practices improved and that participants used the acquired knowledge to make ergonomic changes to reduce or even eliminate pain or discomfort (Harrington & Walker, 2004).

In order to measure the increase in awareness, a good question must be used, that is, the question will measure what it is meant to measure. There are many ways that questions could possibly be asked. Purposeful questions allow the respondents to easily identify the relationship between the question being asked and the objectives of the study (Fink, 2003). Open questions allow for free form responses which allow for unanticipated answers, which is good for qualitative research (Fink, 2003). Closed questions only allow for fixed answers, but are easier to statistically analyze and interpret and responses have a higher chance of being reliable over time (Fink, 2003). Concrete questions are precise, unambiguous and express entire thoughts in complete sentences (Fink, 2003). The concreteness of a question can be augmented by defining possible ambiguous terms or by adding a dimension of time (Fink, 2003). Particularly in this study, low back pain was involved in the question, and although low back pain can be caused by a single instance of lifting (known as acute trauma), the interests of this study were more related to the development of a low back injury or an MSD (known as cumulative trauma), and thus, included a component of time (Caley & Janiszewski, 1995). Therefore, the question used in this study strived to be purposeful, unambiguous, straight-forward and used correct grammar and syntax, so that the responses received had a higher chance of being more reliable and valid (Fink, 2003).

Increased awareness was quantified using questions with a Likert response format which, when summed, create a Likert Scale (Carifio & Perla, 2007). The Likert scale is a psychometric scale that is used in survey research (Likert, 1932). An 11-point response format was used for this study. Studies have shown that the 11 point Likert scale (from 0 to 10) has higher sensitivity, higher normality and comparable reliability when compared with lower point Likert scales (Leung, 2011). It is recommended to use a wide a scale as possible, because rating values can always be collapsed into bins; however, this widening of the scale should not be so much so as to affect reliability (Cummins & Gullone, 2000; Likert, 1932). Although the number choices were evenly spaced, only the very ends were labelled. This was to create data that was more interval in scale because labelling all numbers with non-standardized points of reference (for example, the term "good" when describing an object is ambiguous and will have different meanings depending on the respondent) would have created categories that were assuredly not equal in their intervals (Cronbach, 1946; Cummins & Gullone, 2000). The end points of the scale were labelled with two absolute ends. Although absolute end points tend to result in frequencies concentrating in the middle of the scale, they will also aid in making the Likert scale more of a ratio scaled measurement; therefore, one end of this scale denoted a 0% chance and the other denoted a 100% chance (Wyatt & Meyers, 1987). The Likert scale was chosen over other psychometric measures such as the Visual Analog Scale (VAS) because it requires less time to teach people how to use it and the data it produces is easier to interpret and analyze (Bolognese, 2003; Guyatt & Townsend, 1987). Further, provided the scale has at least 7 points, the Likert scale has been shown to perform with similar sensitivity and reliability when compared to the VAS (Grant & Aitchison, 1999; Impellizzeri & Maffiuletti, 2007; Parker, McDaniel, & Crumpton-Young, 2002).

The rationale behind only attempting to increase awareness or knowledge is in the hopes that participants' self-efficacy will increase and they will be able to recognize possible risks and implement their own interventions and changes to reduce MSD risk factors and disabilities. In order to affect MSD health outcomes, recognition is an essential step in the treatment and prevention process; however, only being able to recognize risk factors is not a sufficient condition for success.

2.6 The Effectiveness of Training

Education and training are ways to transfer knowledge, skills and behaviours required to thrive in a given workplace (Noe, 2002). Specifically, occupational health and safety training strives to provide knowledge on items such as hazard identification, equipment use, and safe work procedures (Robson, 2010). Although the differences between the definitions of education and training are not consistent, for the purposes of this study, training was defined as learning that required time for practice and hands-on practical work in addition to education while education was defined as simply the dissemination of information. There are 4 outcomes by which education can be measured: Knowledge, Attitudes & Beliefs, Behaviours, and Health (Robson, 2010). Measurements may be done immediately, at one month (short-term), at up to six months (intermediate-term), and at greater than six months (long-term) (Robson, 2010). Outcomes for this study were measured immediately.

There are many modes through which training can be done. Since people absorb information differently due to aspects of the learning process being influenced by the different types of training, it can be suggested that training programs can use a variety of methods or even a mix of multiple methods (Kozma, 1991). However, because the overall goal of this study was to be able to raise awareness of risk factors for people learning using educational messages, possibly via a mobile application, only the one method of computer instruction was examined (Verbeek et al., 2012).

Although different training methods can affect knowledge transfer, there are additional factors that affect training effectiveness and outcomes. The first factor is the level of engagement required by the workers. Levels of engagement, which can be categorized as low, medium or high, are heavily correlated with how much interaction occurs between participant and instructor (M. J. Burke et al., 2006). Low engagement methods will have neither interaction nor feedback and tends to consist of passive learning while high engagement training involves highly interactive hands-on training where participants are conditioned to perform work practices safely and properly (Robson, 2010). Depending on the elements being taught, engagement has been shown to have varying effects on learning outcomes. For skills training, higher levels of engagement aid in the experiential learning process (M. Burke, Holman, & Birdi, 2006). Other studies investigating the effects of engagement level on knowledge acquisition have, overall, found insufficient evidence supporting the notion that higher engagement training is more effective than low/medium engagement training (Brahm & Singer, 2013; Robson, 2010). Another factor is intensity of the training exposure. Training can be categorized as high, medium or low intensity and is determined by the length of each training session and the number of sessions workers must attend. A study investigating the effects of training session length on typing ability showed that more time spent per session does not equate to better performance (Baddeley & Longman, 1978). There seems to exist an optimal training session length and overall cumulative training length (Baddeley & Longman, 1978; Baddeley, 1997; Ericsson, 2004).

Training has mixed effects on injury prevention outcomes. A study done by Holmes et al. studied body mechanics education on work performance using an instructional video, demonstrations and some practice, found that there was improvement in lifting technique (good lifting behaviour was assessed to be lifting with bent knees, neutral spine and with the load close to the body with feet at shoulder width and pivoting when necessary) and knowledge (assessed by administering a quiz before and after the educational intervention) (Holmes, Lam, Elkind, &

Pitts, 2008). On the other hand and on a greater scale, a systematic review done by Martimo et al. synthesized 11 randomized and cohort studies and through comparing effect sizes and odds ratios, found that training effects were very small and thus, concluded that there is no evidence to support the use of advice or training in working techniques for the prevention of low back pain and disability (Martimo, Verbeek, & Karppinen, 2008). Furthermore, a systematic review done by Robson et al. looked at 22 studies and found that although training was effective at affecting worker OHS behaviours, they also concluded that there was insufficient evidence of the effectiveness of training on health outcomes and that the insufficient evidence is due to there being a lack of high quality, randomized control trials with pre and post intervention measures. Both of these reviews showed that confounding factors can make it more difficult to determine if training has a significant impact on long term outcomes. These factors have to do with the individual and the workplace. Individuals have varying demographic backgrounds, cognitive abilities, motivations, previous knowledge, and learning styles (Robson, 2010). Individuals experience behavioural change differently, and thus, results of educational outcomes can vary from failing to recognize a health risk to ergonomic changes actually taking place (Haslam, 2002). Workplace attitudes towards OHS training can also affect training outcomes. It is these factors that could be the explanation for the lack of an effect seen in training efficacy studies on the prevention of MSDs.

Educational efficacy on behavioural change and the subsequent improvement in health outcomes has many intricate factors; therefore, this study focused on raising immediate awareness in participants through the use of a low engagement, computer instructed, low intensity educational message that would reflect the educational properties of a mobile application.

2.7 Literature Review Summary

To summarize:

- LBP is modulated by many physical risk factors that can be related to the individual or to the work task variables.
- The 1991 NIOSH Equation is one of many manual materials handling evaluation methods and although its measures can seem conservative at times, epidemiological evidence exists to support the efficacy and validity of using it as a risk factor analysis tool and it seems to be the most conducive method for understanding how different inputs impact lifting exposures.
- Lower originating lifts increase risk of developing LBP. Furthermore, wearing an abdominal belt can also increase injury risk during lifting tasks.
- Participatory ergonomics can be an effective and useful tool in preventing and decreasing musculoskeletal disorders, particularly when workers have been trained and educated to help assess risks in the workplace and to give their input in the creation and implementation of solutions.
- Studies utilizing workers for task analysis have shown that workers can be trained to use risk factor checklists, questionnaires or posture matching software almost as well as trained ergonomists; however, more work needs to be done to investigate whether simpler and less tangible concepts can be acquired and used by workers.
- Knowledge transfer can significantly alter participant awareness and awareness can be measured by conceptual knowledge utilization. Most studies in the past have used forms

of quizzes to assess knowledge acquisition; however, this study used a Likert Scale to measure perceived risk.

- Finally, there exist many intricate factors or steps between implementing occupational health & safety education/training and their observed health outcomes and although there is insufficient evidence to support the notion that education/training can affect health outcomes, immediate conceptual knowledge utilization can be used to measure knowledge transfer.

3. Methodology

3.1 Methods Overview

This study began with filming multiple lifting tasks with individuals from several backgrounds. These videos were input into an online web-based survey. The online web-based survey involved a 25-35 minute session where participants: filled out a demographic survey, watched and rated each lifting instance video, and read a brief educational message at the midway point of the video rating trials. Post-collection processing and analysis quantified how well participants were able to recognize LBP risk factors pre- and post-educational intervention and the correlation between various participant demographic-stratified groups and a chosen standard.

Participants consisted of 178 people recruited verbally, through e-mail and with the help of three health and safety associations to do the online or paper version of the survey. These participants were selected from a number of sectors and in different types of positions (e.g. workers, supervisors, small business owners, and health & safety consultants). We recorded self-selected ergonomic experience levels as a covariate. All participants had the purposes, methods, risks and benefits explained to them before they gave consent in order to join the study. Each participant also received a feedback letter after participating outlining the study details and researcher contact information. This study was reviewed by and received ethics clearance through an institute's research ethics committee.

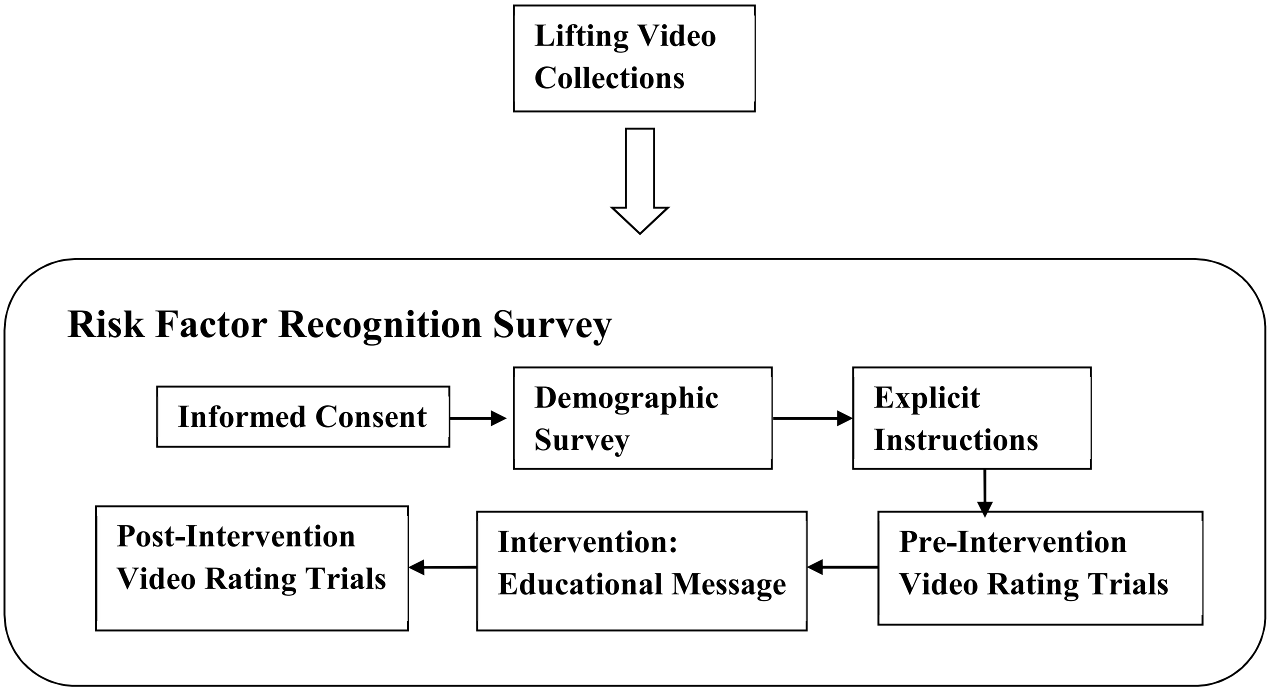


Figure 3.1 Block diagram of study overview. Each box within the Risk Factor Recognition Survey area represents a different section of the survey that participants completed.

3.2 Video Collection of LBP Risk Factors

Ten-second videos of lifting instances were captured using a single video camera (Sony HDR-SR11, Sony Corporation, Tokyo). Although there is evidence that two cameras should be used to capture postures in the frontal and sagittal planes for posture analysis, only one camera was used because that is how many points of view a single person would have (Andrews et al., 2008). With using only one camera, great care was taken to show all lifting instances from angles that highlighted or showed the most important variables of each lift. Previous work by Takala et al. have shown that video observational methods that assess biomechanical exposures for large-scale body postures and work actions have good inter-rater reliability (Takala et al., 2010). Since lifting is a large-scale work action, participants were able to see body postures;

however, since it has been stated that twisting can be difficult to discern, additional consideration was put into filming and choosing the asymmetrical lift videos.

Lifting instances that differed in various factors were filmed and used in the survey (Table 3.1). Six lifting heights were used as vertical origins and destinations (VH). Eight different height combinations were used to make lifting tasks less distinguishable from one another and more natural. All lift videos were shown in a randomized order during the pre-intervention video rating trials and the duplicates of the videos were also shown in a randomized order during the post-intervention video rating trials.

The video participants who were video recorded consisted of, but were not restricted to: 2 graduate students and 8 various workers with differing degrees of manual materials handling experience. These participants were recruited verbally with the help of three health and safety associations and a university health and safety office. Exclusion criteria for video participation included a history of low back pain in the past 6 months. These lifters first had the purposes, methods, risks and benefits of the study explained to them before they signed a media release waiver allowing the use of their lifting videos for the risk factor recognition survey. Any facial features that were visible in these video recordings were not censored or blackened out to allow for the natural perception of a lift.

Three categories of mass were used to catalogue objects. The props that were lifted were considered light (< 1 kg/< 2.2 lbs) (LIT), medium (3-10 kg/6.6-22 lbs), or heavy (> 15 kg/33 lbs) (HEV); however, weights lifted by participants did not exceed the maximum acceptable weight limits for 75% of males (or females, depending on the participant's sex) (Snook & Ciriello, 1991). Since it could be difficult to judge the weight of an object that is being lifted in a video, relatable or everyday items were used. For example, light objects that were used were a pen or a piece of paper, medium objects that were used were a two handed power tool or 2-4 bags of ice and heavy objects that were used were a large floor stone or a box of 24 bottles of beer. Additionally, the actual weight of the object in the video was displayed in both pounds and kilograms to increase the amount of information given to the viewer so they could better relate to the lifts in the videos. The default weight category was medium.

The NIOSH variables that were manipulated were frequency (FREQ), horizontal distance (HORI), asymmetry (ASY), or coupling (CUP). The default frequency used was one lift within the 10 second video and when manipulated, became a task requiring lifting at a rate of approximately 8 lifts per minute. The default horizontal distance was approximately 10 inches and when manipulated, became a task requiring a reach of 20 inches or more. The default asymmetry angle was 0° and when manipulated, became a task requiring at least a 45° angle from the lifting subject's sagittal plane. Finally, the default coupling of the objects to be lifted was good and when manipulated, became a task requiring poor coupling.

Video lifters were asked, by default, to lift using a squat lift with a neutral/lordotic spine. For manipulated videos, lifters were asked to use a stoop lift technique (STP). Previous studies have evaluated the advantages and disadvantages of stoop, squat and semi-squat low-lying lifts using various criteria (for example: psychophysical, physiological, and biomechanical criteria) and found no single lifting technique outperforms the other two across all criteria examined (Straker, 2002, 2003).

Table 3.1: Lifting Videos. Forty-Four lifting tasks that were filmed organized by factor. Each cell represents one lifting trial unless otherwise specified. The lifting height combinations are from Calf-to-Waist (CW), Floor-to-Floor (FF), Floor-to-Shoulder (FS), Floor-to-Waist (FW), Knee-to-Waist (KW), Thigh-to-Waist (TW), Waist-to-Shoulder (WS), and Waist-to-Waist (WW).

Vertical Height (VH) (8 Combos)	Lower (LOW) (3 Combos)	NIOSH Variables: Frequency (FREQ) (3 Combos)	NIOSH Variables: Horizontal Reach (HORI) (3 Combos)	NIOSH Variables: Asymmetry (ASY) (3 Combos)	NIOSH Variables: Coupling (CUP) (3 Combos)	Stoop (STP) (2 Combos)	Weight: Light (LIT) (5 Combos)	Weight: Heavy (HEV) (5 Combos)	Back Belt (BB) (1 Combo)
F -> W*	W -> F	F -> W	F -> W	F -> W	F -> W	F -> W	F -> W	F -> W	F -> W
C -> W	W -> C						C -> W	C -> W	
K -> W*	W -> K					K -> W	K -> W	K -> W	
W -> W*		W -> W	W -> W	W -> W	W -> W		W -> W	W -> W	
F -> F*		F -> F	F -> F	F -> F	F -> F		F -> F	F -> F	
T -> W									
F -> S									
W -> S									

*= Three trials

Table 3.2: Lifting Factor Rationales

Factor	Rationale
1) Vertical Height - Lifting from/to multiple heights to -Repeated videos were to oversample waist, knee and floor lifts. -Shoulder height lifts were under-sampled	-To find if participants know that "low" lifts have a higher risk of LBP. -To emphasize activities related to the key message -The focus of the study is LBP
2) Lowering -Only at waist, knee and floor heights only	-Principle is as applicable to controlled lowering -To reduce number of trials
3) Other NIOSH Variables -Only those at waist and floor level	-Although not the focus, this is valuable information in a larger context -To reduce number of trials
4) Alternate Lifting Technique -Only at floor and calf level	-To see how current recommendations affect peoples' risk perception -Maximize effect and to reduce the number of trials
5) Different Weights	-To determine perceptions of the effect of weight
6) Abdominal Belt	-To see how current recommendations affect peoples' risk perception

Lifting Heights: S = Shoulder; W = Waist; T = Thigh/Knuckle; K = Knee; C = Mid-Calf; F = Floor/Ankle

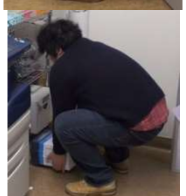
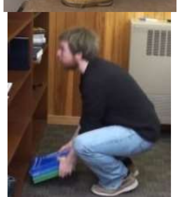
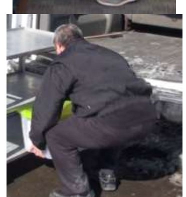
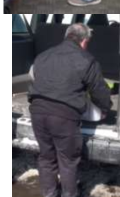
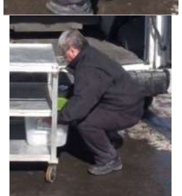
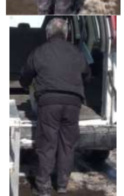
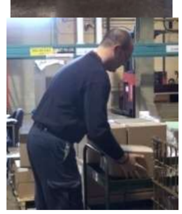
NIOSH Variables: FREQ = Frequency; HORI = Horizontal Distance; ASY = Asymmetry; CUP = Coupling

Each lifting instance was filmed multiple times from different camera angles and the video with the best overall view of the task was selected to be put into the survey. Videos of lifting instances were filmed so that they seemed as natural as possible and included natural workplace distracters. For example, workers walked into frame, performed the task and simply walked towards their next work duty until they were out of frame. Distracters were other workers working in the background, noises and sounds of various machines being operated or other things that naturally occurred in a work place. Although distracters were included in the videos, care was taken in controlling the lifting settings so that environmental conditions , such as lighting, noise, temperature, and worker/floor surface coupling did not greatly influence lifting performance (OSHA, 1910; Waters & Putz-Anderson, 1994). For instance, Davis et al. (1997) investigated loud, startling noises and their effects of spinal musculature and found that noises could produce muscle activity of up to 2.5 times more than a quiet condition in some participants.

Additional lifting guidelines were provided for lifters based on the NIOSH lifting equation limitations. lifters were instructed to keep non-lifting MMH tasks (such as holding, pushing, pulling, carrying, walking and climbing) to a minimum so as to not account for more than 10% of total work energy expenditure (Waters & Putz-Anderson, 1994). Therefore, each lifting task was restricted to taking 2 steps or fewer and the holding of the objects did not exceed 3 seconds. Although the NIOSH equation does not assess one-handed lifting tasks, for the purposes of filming lifts that seem natural, one-handed lifts were allowed, however, lifters were instructed to avoid twisting their trunks as they bent forward to lift an object in the sagittal plane. Furthermore, the hand not performing the lift was not permitted to be used to support or brace the lifter. Lifting tasks were designed so they were performed in a standing or squatting posture;

lifts were not performed in constrained/restricted workplaces, nor were they performed while seated or kneeling. Finally, lifts did not exceed a speed of 30 inches per second and the objects that were lifted were stable (i.e. the center of mass did not vary significantly during the lifting activity) (Waters & Putz-Anderson, 1994).

Table 3.3 Stills of Eight Vertical Height Combinations of a Medium Lift.

Task	Origin	Destination
Floor to Floor		
Floor to Waist		
Floor to Shoulder		
Calf to Waist		
Knee to Waist		
Thigh to Waist		

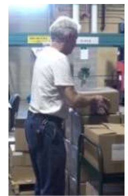
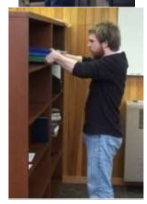
Waist to Waist		
Waist to Shoulder		

Table 3.4 Stills of Lifting vs. Lowering at 3 Height Combinations.

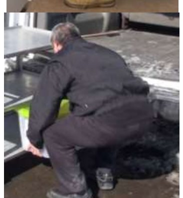
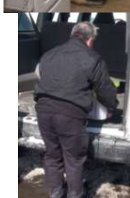
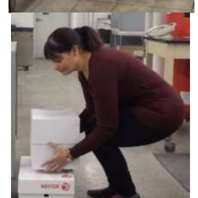
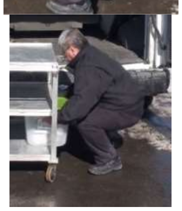
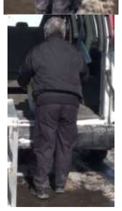
Lifting from	Origin	Destination	Lowering from	Origin	Destination
Floor to Waist			Waist to Floor		
Calf to Waist			Waist to Calf		
Knee to Waist			Waist to Knee		

Table 3.5 Stills of Symmetric and Asymmetric Lifts at the Origin or Destination.

Height Combination	Sagittal	Twist
Floor to Floor		

Floor to Waist		
Waist to Waist		

Table 3.6 Stills of Good and Poor Coupled Lifts at the Origin.

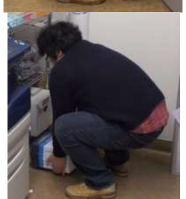
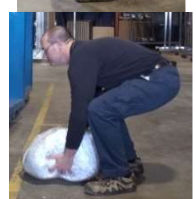
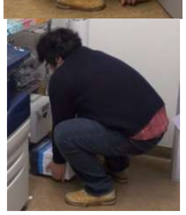
Height Combination	Good Coupling	Poor Coupling
Floor to Floor		
Floor to Waist		
Waist to Waist		

Table 3.7 Stills of Single Instance and Repeated Lifts.

Height Combination	Single	Repeated
Floor to Floor		
Floor to Waist		

Waist to Waist		

Table 3.8 Stills of Near and Far Lifts.

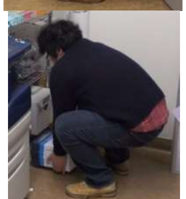
Height Combination	Near	Far
Floor to Floor		
Floor to Waist		
Waist to Waist		

Table 3.9 Stills of Squat and Stoop Lifts at the Origin.

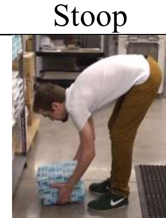
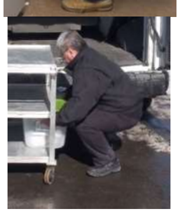
Height Combination	Squat	Stoop
Floor to Waist		
Knee to Waist		

Table 3.10 Stills of Light, Medium, and Heavy Lifts at the Origin.

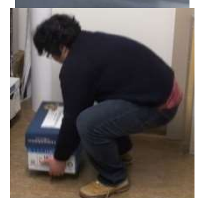
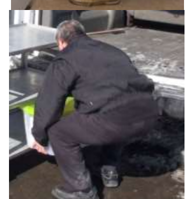
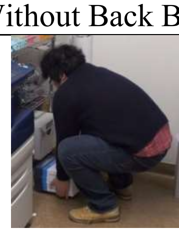
Height Combination	Light	Medium	Heavy
Floor to Floor			
Floor to Waist			
Calf to Waist			
Knee to Waist			
Waist to Waist			

Table 3.11 Stills of Lifting With(out) a Back Belt.

Height Combination	Without Back Belt	With Back Belt
Floor to Waist		

3.3 Simple Educational Messages

Two educational intervention pieces were used in this study. One message was used as an intervention, and the other, as the control. Participants were split randomly and equally into the intervention and control groups. Both messages consisted of a small paragraph of text outlining the respective risk factor issues, some mechanisms as to why they exist, and how they affect the workplace. The control educational message was based on evidence-based research regarding the use of abdominal belts; the message was called the control condition because there was only one abdominal belt used in one of the videos that were filmed, therefore, it should not have affected the ratings participants gave for the other post-intervention videos. The rationale behind having a control message was to investigate if the changes seen between pre- and post-intervention trials were really due to the educational message, or if participant awareness changed simply by repeating the questionnaire with duplicate videos. The final messages below were reviewed and refined with the help of a research team and a project stake-holder panel.

The first message was as follows:

> *"The closer your hands are to the ground when you are lifting an object, the more likely you will hurt your back. Even when lifting light objects, you can hurt your back. There is no "best" way to lift things from the ground, so to stop that problem altogether, 'Store if off the floor!'"*

The second message was as follows:

> *"Back belts are sometimes used in work places to prevent low back pain. However, research shows back belts can increase the seriousness of an injury. Although people feel they can lift more weight when using them, they may lift too much weight and hurt themselves. Belts should only be used temporarily."*

3.4 Development of a Survey to Assess Workers' Ability to Recognize LBP and the Effect of a Short Educational Message

Online web surveys were developed with the aid of a health and safety association. Apart from a demographic survey page, each video rating page layout consisted of a media viewing window, the rating question and an 11-point Likert scale (Figure 3.2). Additionally, each page had a progress bar indicating how far along the participant was in the survey (Crawford, 2001). Once the participant selected a number they were content with, they clicked the button that allowed them to progress to the next page of the survey. Upon completion of all trials, the participants were debriefed by the researcher and, during pilot testing, were given the option of giving feedback so that any comments, notes or improvements could be taken into account and adjusted for (Fan & Yan, 2010; Fink, 2003).

3.4.1 Demographic Survey

Participants completed a demographic survey that provided further insight into between subject factors. In addition to sex, age, height and weight, the following items were asked:

Table 3.12: Demographic Survey Items. The items that were asked are listed below with example question or answers and rationale behind each item.

Item	Examples	Rationale
Position in company	-Worker, supervisor, employer, health and safety representative	Previous literature has shown that position in a company can affect familiarity with ergonomics and ability to assess risk (Winnemuller et al., 2004)
Familiarity with ergonomics	0-5 point Likert scale with anchors at the ends: "Not familiar at all" and "Very familiar"	
Sector	-Finance, construction, manufacturing, food, transportation… etc.	Previous literature has shown that sector differences and increase in worker experience can affect risk assessment and posture analysis (Andrews,
Work Experience	-<1 year, >1 and <5 years, >5 and <10 years, >10 years	

		Holmes, et al., 2008; Weir et al., 2007)
Previous low back injury	Within last 6 months, within last year, within last 5 years, never	Patients with LBP can show reduced perceptions of physical capacity(Dolce, Crocker, Moletteire, & Doleys, 1986)
Workplace size	<20 employees, >20 and <50 employees, >50 employees	Small businesses (companies with < 20 workers) have been shown to not have access to information about ergonomics. If it can be shown that the individual workers can learn to be aware of risk factors, it provides more incentive for transferring knowledge to small businesses.

Once participants filled out the demographic survey, explicit instructions were given on how to rate video trials so participants could successfully finish the survey and provide good data.

3.4.2 Video Rating Trials

For each of the 88 video rating trials, the same question asked the participant to rate how likely the lifting instance would lead to low back pain using an 11-point Likert scale (Figure 3.2). The purpose of the question was to assess how aware each participant was of the risk factors associated with lifting. The Likert scale was used to quantify each participant's risk of LBP rating.

The question was as follows:

> *"Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain."*

The Likert scale used in this study was as follows:

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

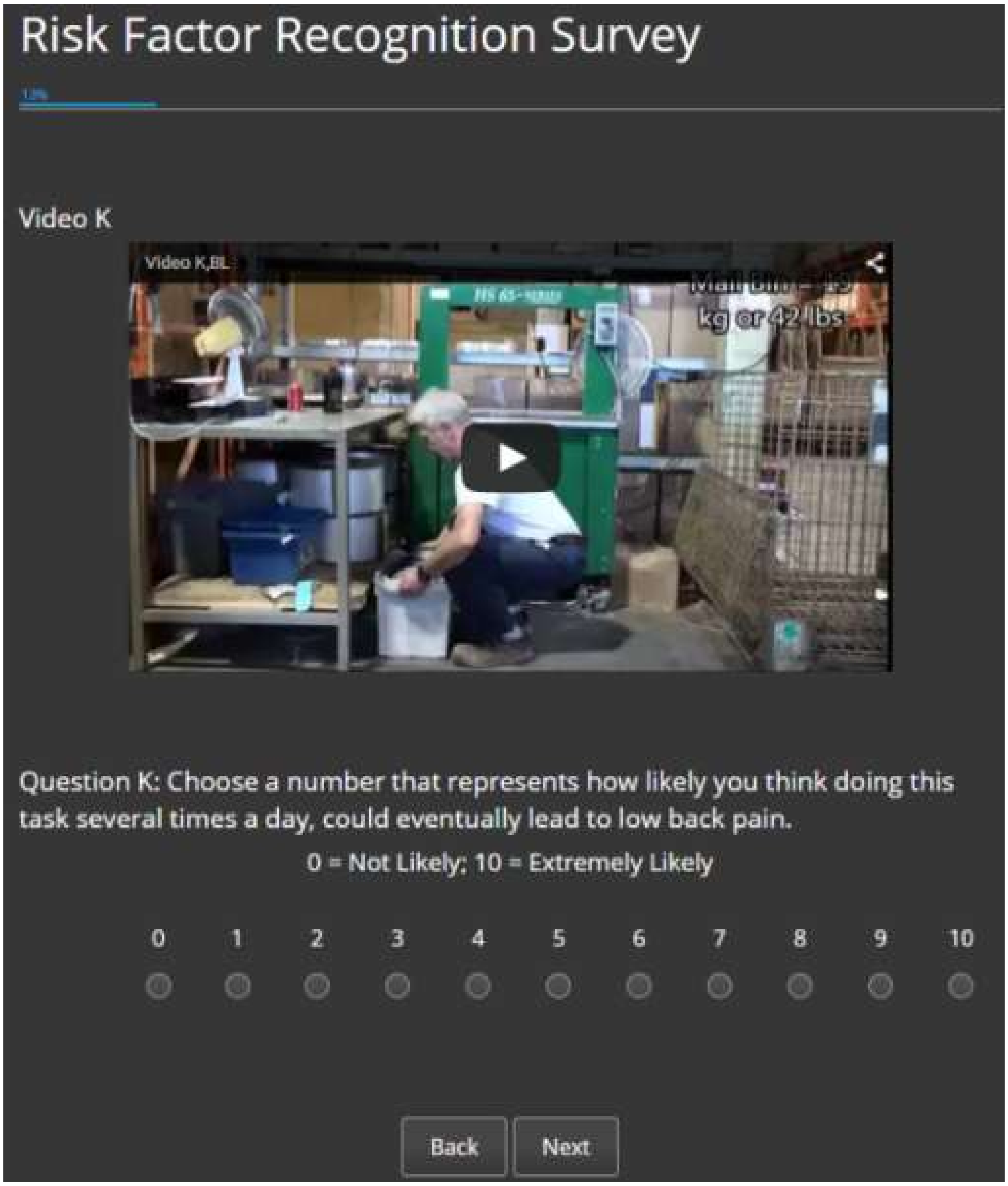


Figure 3.2 Screen capture of a video rating trial using FluidSurveys™.

3.5 Lifting Risk Assessment

Lifts were posture sampled to estimate low back injury risk. Each lifting video had up to twelve frames collected and input into 3DMatch (University of Waterloo, Canada), an industry used posture sampling tool that uses user-selected posture bins, in addition to subject details and force direction inputs to calculate low back loading levels. 3DMatch is a top-down rigid link segment model that combines a single muscle equivalent and a polynomial model to predict spinal compression, shear, and moments (McGill, Norman, & Cholewicki, 1996; Sutherland, Albert, Wrigley, & Callaghan, 2008). Many studies have been done to support the reliability, validity, and use of this sampling tool to provide estimates of low back loading (Andrews, Fiedler, Weir, & Callaghan, 2012; Parkinson, Bezaire, & Callaghan, 2011; Sutherland, Albert, Wrigley, & Callaghan, 2007; Sutherland et al., 2008). Frames of videos were selected based on the phase of the lift (an example of this can be seen in Figure 3.3). The three points in the lift were the Lift-Off phase (when the entirety of the object's weight was first being lifted), the End phase (the point at which the object was just about to be put down) and the Mid phases (these were sampled depending on the length of the lifting video and varied in number from zero to ten frames). To keep the spinal loading values consistent from one lifting video to another, the subject inputs used for 3DMatch emulated those of a 25 year old, 50th percentile male living in North America (approximately 75 kg and 1.75 m tall) (McDowell, Fryar, Ogden, & Flegal, 2008). The force inputs were assumed to always be in the negative Y direction (down, based on ISB standards) and were evenly split between right and left hands (weight was distributed symmetrically throughout the load) (Wu et al., 2005). The postures chosen from bins were based on the frame of interest. Low back load outputs were saved for further processing. To give each lift a value of risk and to enable the comparison of shear and compression values, force values were normalized to their respective NIOSH action limits (500 N for shear and 3400 N for compression) (Herkowitz, Dvorak, Bell, Nordin, & Dieter, 2004; McGill, Norman, Yingling, Wells, & Neumann, 1998). The maximum normalized risk value was then selected from all of the frames analysed for each lifting video and was used in statistical processing and analyses.

Figure 3.3 Example of 3 video frames collected from the heavy, knee-to-waist lift to use as input in 3DMatch. The pictures (from left to right), show the subject just lifting the object (Lift-Off phase), during mid lift (Mid phase), and just before the subject places the object down (End phase).

3.6 Testing People's Ability to Recognize LBP Risk Factors and the Effectiveness of the Message

Likert scale values were processed for analysis. Data were processed with MATLAB software version 2013 (Mathworks Inc., Massachusetts, USA) and statistical analyses were performed using SAS 9.4 statistical software (SAS Institute Inc., North Carolina, USA). Shapiro-Wilk tests of normality were done on the data and it was shown that the data were not normally distributed. However, parametric tests were still used to analyze the data due to reasonably large sample sizes and the robustness of using F-tests on non-normal data (G. Norman, 2010). Statistical level of significance was considered at an $\alpha = 0.05$.

3.5.1 Investigation #1: Risk Perception of Lifting Factors

To find out which low back pain lifting risk factors participants perceived as riskier than others, various factorial ANOVAs were run on the Pre score Likert data (Table 3.13 to Table 3.19). A Tukey-Scheffe post-hoc test was performed for the multiple pair-wise comparisons. The Tukey-Scheffe test was chosen because it is highly conservative and handles comparisons with unequal group sizes well (Einot & Gabriel, 1975; Keselman & Rogan, 1977).

3.5.2 Investigation #2: Message Efficacy

The difference in scores of the same task – pre and post message – indicated the effectiveness of the message. To examine whether the messages changed perceptions of risk, paired t-tests investigating the difference between Pre and Post video rating scores were run and separated by 2 categories: experimental group (x2) and lifting factor (x36). A Bonferroni correction was used to mitigate Type I error.

3.5.3 Investigation #3: Demographics and Correlations

To observe which demographic factors played a large role in whether participants ranked videos similarly to an industry-used posture sampling tool, demographically stratified post-hoc regression Pearson Product Moment Correlations between participant pre scores (perceived risk) and the 3DMatch normalized scores (estimated risk) were run. A Bonferroni correction was used to mitigate Type I error.

Table 3.13: ANOVA Comparisons. Table identifying ANOVAs that will be tested to investigate the effects of each factor. Factors with common videos with the Vertical Height column will be compared using a full factorial design. For instance, a Vertical Height vs. Weight design will consist of 5 height combinations x 3 weights.

Vertical Height (VH)	**Lower (LOW)**	**NIOSH Variables**				**Stoop (STP)**	**Weight**		**Back Belt (BB)**
		Frequency (FREQ)	**Horizontal Reach (HORI)**	**Asymmetry (ASY)**	**Coupling (CUP)**		**Light (LIT)**	**Heavy (HEV)**	
F -> W[A,B,C,D,E,F]	W -> F[B]	F -> W[C]	F -> W[C]	F -> W[C]	F -> W[C]	F -> W[D]	F -> W[E]	F -> W[E]	F -> W[F]
C -> W[A,B,E]	W -> C[B]						C -> W[E]	C -> W[E]	
K -> W[A,B,D,E]	W -> K[B]					K -> W[D]	K -> W[E]	K -> W[E]	
W -> W[A,C,E]		W -> W[C]	W -> W[C]	W -> W[C]	W -> W[C]		W -> W[E]	W -> W[E]	
F -> F[A,C,E]		F -> F[C]	F -> F [C]	F -> F[C]	F -> F[C]		F -> F[E]	F -> F[E]	
T -> W[A]									
F -> S[A]									
W -> S[A]									

[A] = One-way ANOVA comparing lifting height combinations
[B] = 2x3 ANOVA comparing lifting vs. lowering
[C] = 5x3 ANOVA comparing NIOSH Variables with default lifts
[D] = 2x2 ANOVA comparing Stoop lift with default lifts
[E] = 3x5 ANOVA comparing default lifts with altered object weights
[F] = One-way ANOVA comparing lifting without and with a back belt

Table 3.14: One-way ANOVA comparing lifting height combinations.

Vertical Height	F -> W	C -> W	K -> W	W -> W	F -> F	T -> W	F -> S	W -> S

Table 3.15: 2x3 ANOVA comparing lifting vs. lowering.

	Vertical Height		
Lift (Default)	F -> W	C -> W	K -> W
Lower	W -> F	W -> C	W -> K

Table 3.16: 5x3 ANOVA comparing NIOSH variables with default lifts.

		Vertical Height		
Default		F -> W	W -> W	F ->F
NIOSH Variables	Frequency	F -> W	W -> W	F ->F
	Horizontal Reach	F -> W	W -> W	F ->F
	Asymmetry	F -> W	W -> W	F ->F
	Coupling	F -> W	W -> W	F ->F

Table 3.17: 2x2 ANOVA comparing Stoop lift with default lifts.

	Vertical Height	
Squat (Default)	F -> W	K -> W
Stoop	F -> W	K -> W

Table 3.18: 3x5 ANOVA comparing default lifts with altered object weights.

		Vertical Height				
Weight	Medium (Default)	F -> W	C -> W	K -> W	W -> W	F ->F
	Light	F -> W	C -> W	K -> W	W -> W	F ->F
	Heavy	F -> W	C -> W	K -> W	W -> W	F ->F

Table 3.19: One-way ANOVA comparing lifting without and with a back belt

F->W	No back belt	With back belt

4. Results

The participant samples from both message groups have similar characteristics (Table 4.1).

Table 4.1 Description of Participants

Descriptor	Back Belt Group (N=89)	Lifting Height Group (N=89)
Mean Age (SD) (yrs)	34.0 (±12.4)	33.6 (±12.3)
Mean Height (SD) (m)	1.71 (±0.10)	1.71 (±0.10)
Mean Weight (SD) (kg)	75.6 (±18.2)	74.1 (±18.7)
Males|Females	41|45	38|51

4.1 Risk Perception of Lifting Factors

Likert rating scores pre-educational message were taken from participants of both message groups and analyzed to provide insight into what participants perceived as risky for lifting. These ANOVAs used the factors of Lifting Condition/Task (LCondn) and Height Combination (HCWords). Level of significance was chosen to be $\alpha=0.05$.

4.1.1 Vertical Height

When only the height of the task (VH) was manipulated, significant effects on risk perception were found ($p<.0001$, Table 4.2). Overall, it was perceived that the calf-to-waist lift was riskiest (Likert mean = 6.06±2.38, Appendix B: Table 9.1), followed by lifts originating from the floor (Likert mean range = 4.11 to 4.81 ± 2.25 to 2.49, Appendix B: Table 9.1). Lifts originating from the thigh or the waist were seen to be the least risky (Likert mean range = 2.10 to 2.91 ± 1.87 to 2.05, Appendix B: Table 9.1). Since other risk perception sections have ANOVA analyses with vertical height as a factor, should there be a main effect of VH in subsequent sections and it will follow the trends described in this section.

Table 4.2 One way ANOVA using Vertical Height as a factor.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	7	3719.695	531.385	106.30	<.0001
Error	2840	14197.539	4.999		
Corrected Total	2847	17917.235			

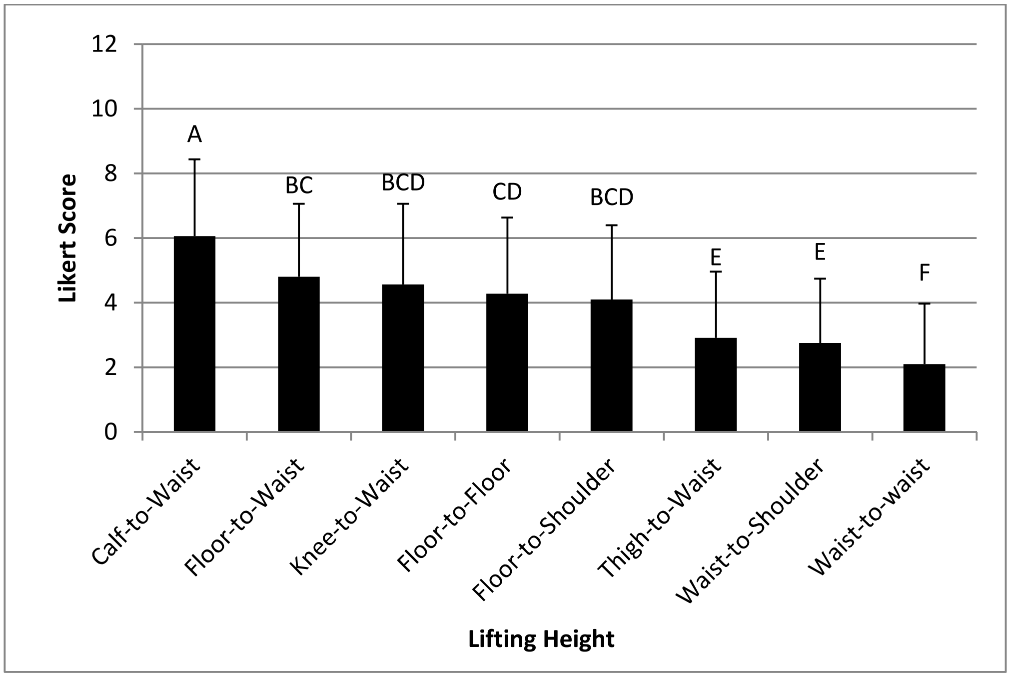


Figure 4.1 Column plot for Vertical Height. Means and one standard deviation are shown. Letters that are the same denote lifting tasks that were perceived to not be statistically different in terms of risk.

Reasons as to why the Calf-to-Waist lifting video received unexpectedly high rating scores will be offered in the discussion section below.

4.1.2 Lifting vs. Lowering

Lifting and lowering (LOW) were compared for three lift heights (VH) and significant interaction and main effects on risk perception were found (p<.0001, Table 4.3). Lifting was seen to be riskier than lowering for lifts originating from the calf or knee but was seen to be not significantly different from lowering when originating from the floor (p<.0001, Table 4.3, Figure 4.2 & Figure 4.3). Lowering to different heights had a significant main effect on risk perception

(p<.0001, Table 4.3, Figure 4.4). The post hoc test results show that lowering an object to the floor was perceived to be significantly riskier than lowering to the calf or knee heights (p<.0001, Figure 4.4) while lowering to the calf or knee height was perceived to not be statistically different from one another (p=0.0759, Appendix B: Table 9.4). The mean Likert score for lowering to the floor was 4.92 (±2.54) compared to lowering to the calf (3.99 ± 1.96) or knee (3.21 ± 1.94) (Full table of descriptive statistics is in Appendix B:Table 9.3).

Table 4.3 Two Way ANOVA using Vertical Height (VH) and Lifting/Lowering (LOW) as factors.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	5	829.437	165.887	31.00	<.0001
Error	1774	9492.537	5.351		
Corrected Total	1779	10321.975			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
LOW	1	419.535	419.535	78.40	<.0001
VH	2	364.953	182.477	34.10	<.0001
LOW*VH	2	284.476	142.238	26.58	<.0001

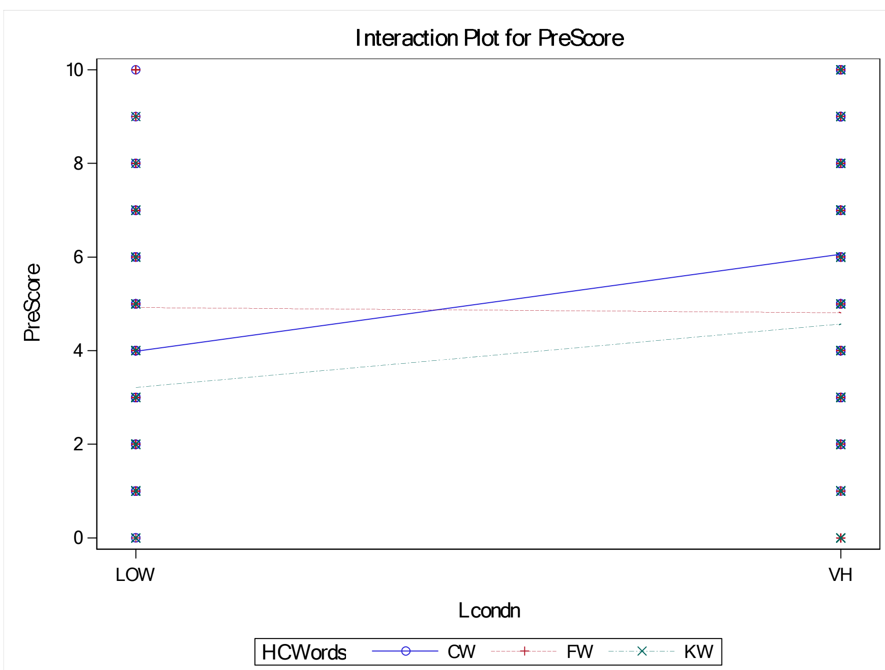


Figure 4.2 Interaction plot for two way ANOVA of Lifting (VH) vs. Lowering (LOW). The Likert scores (PreScore) of various height combinations (HCWords) are shown for the Calf-to-Waist (CW), Floor-to-Waist (FW), and Knee-to-Waist (KW) lifts.

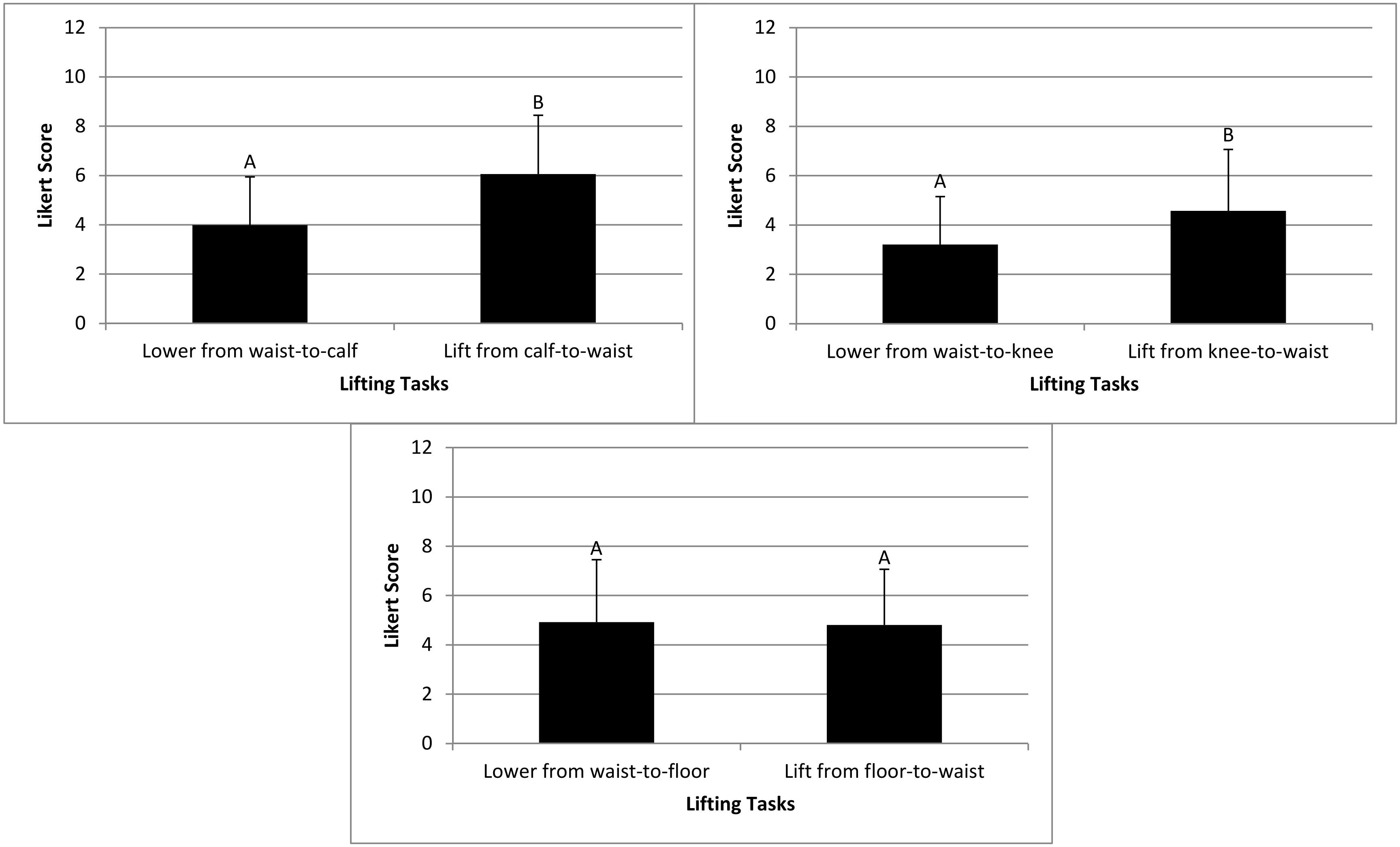


Figure 4.3 Column plots for the Lowering vs. Lifting two way ANOVA. Means and one standard deviation are shown. Letters that are the same denote lifting tasks that were perceived to not be statistically different in terms of risk.

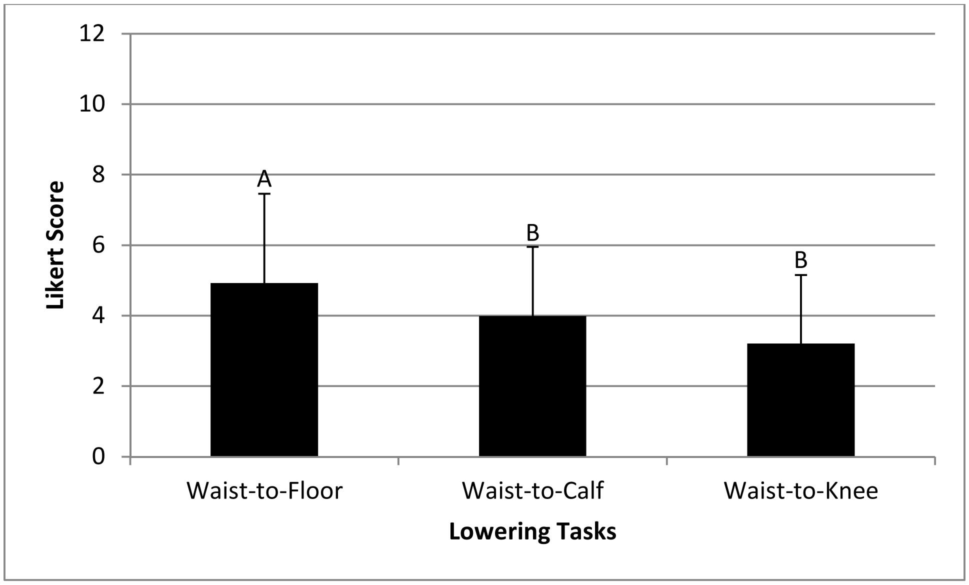


Figure 4.4 Main effect plot for Lowering. Means and one standard deviation are shown. Letters that are the same denote lifting tasks that were perceived to not be statistically different in terms of risk.

Since differences were seen at two heights combinations but not the third, a closer inspection of the FW lift and lowering tasks was done. Specifically, the lift and lower tasks that mirrored each other were investigated (except for the task itself, all other factors were the same for the third FW lifting task and the FW lowering task). From further analysis of these two videos it can be seen that the lowering task was, on average, rated lower than the lifting equivalent of the task (lifting average = 5.75 ± 2.02 and lowering average = 4.92 ± 2.54). A simple paired t-test showed that the two samples were statistically different at a level of significance of α=0.01. From the histogram plots below, a much larger portion of the participant sample believed lowering was less risky than lifting even if one of the tasks began or ended at the floor (Figure 4.5). This evidence could suggest that regardless of height, lowering could always be perceived as less risky than lifting.

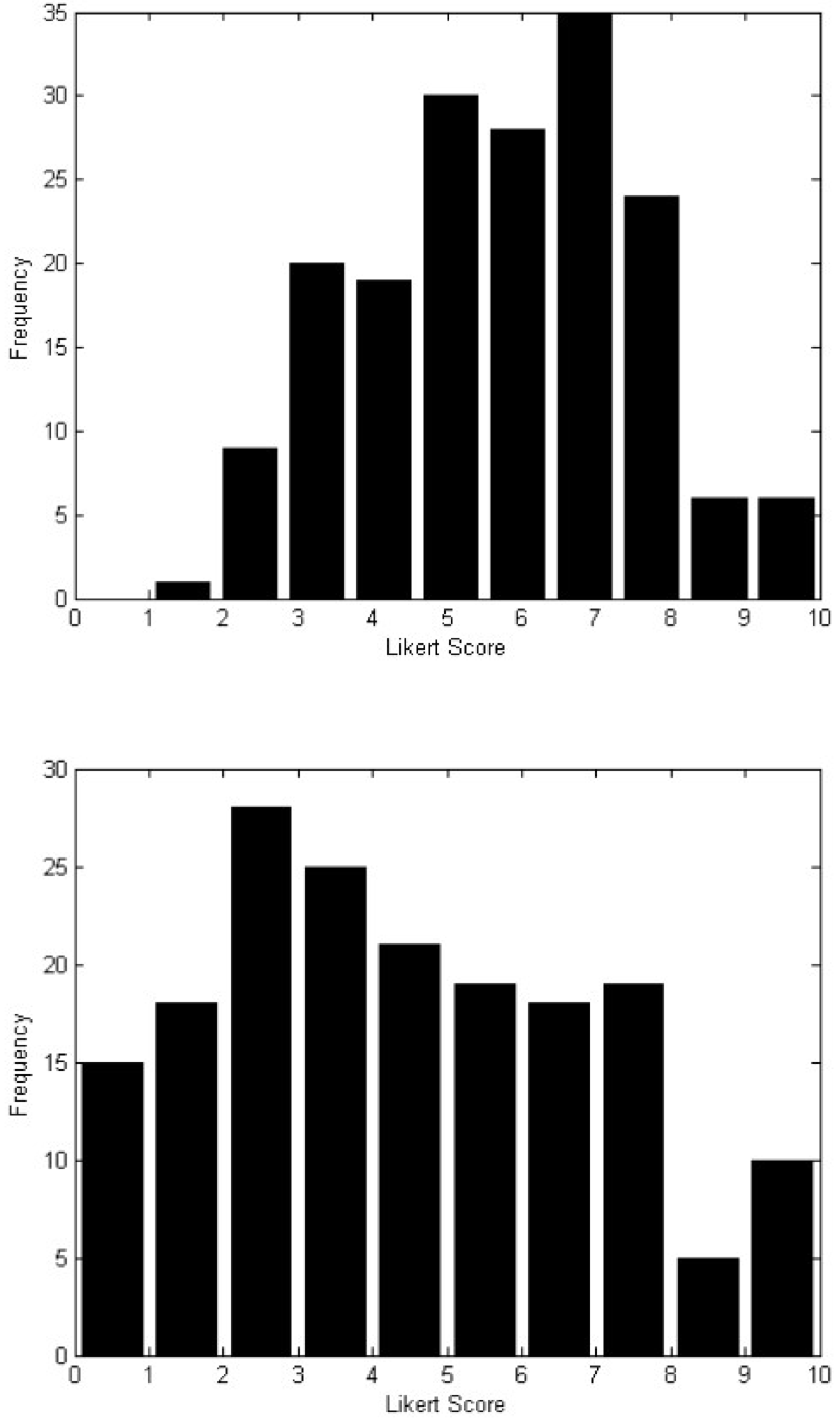


Figure 4.5. Histogram plots of the third Floor-to-Waist Lifting video (Top) and the Waist-to-Floor Lowering video (Bottom). Aside from the difference in task (lifting vs. lowering), the participant, object lifted, and lifting heights/destinations were all the exact same.

4.1.3 Asymmetric Lifts

There were significant interaction and main effects of twisting lifts (ASY)/purely sagittal lifts (VH) vs. height combination on risk perception ($p<0.05$, Table 4.4, Figure 4.6). Although there was a small interaction effect, in general, the tasks that required twisting were perceived to be significantly riskier than their purely sagittal counterpart lifts (Figure 4.7). Additionally with the asymmetric tasks, lifts from the floor were perceived to be riskier than lifts starting at the waist.

Table 4.4 2x3 ANOVA using Asymmetry (Lcondn) and Lifting Height Combination (HCWords) as factors.

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	5	4117.735	823.547	170.070	<.0001
Error	2130	10314.305	4.842		
Corrected Total	2135	14432.041			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Lcondn	1	746.406	746.406	154.140	<.0001
HCWords	2	2806.771	1403.385	289.810	<.0001
Lcondn*HCWords	2	58.344	29.172	6.020	0.0025

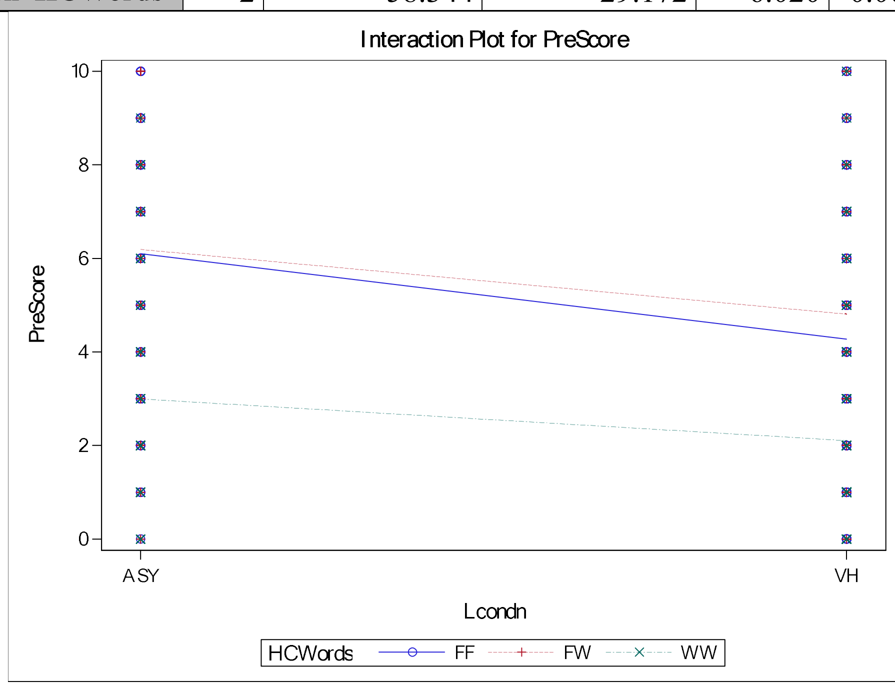


Figure 4.6 Interaction plot for 2x3 ANOVA of Twisting (ASY)/Sagittal (VH) lifts vs. Vertical Height Combinations (HCWords). The Likert scores (PreScore) of various height combinations (HCWords) are shown for the Floor-to-Floor (FF), Floor-to-Waist (FW), and Waist-to-Waist (WW).

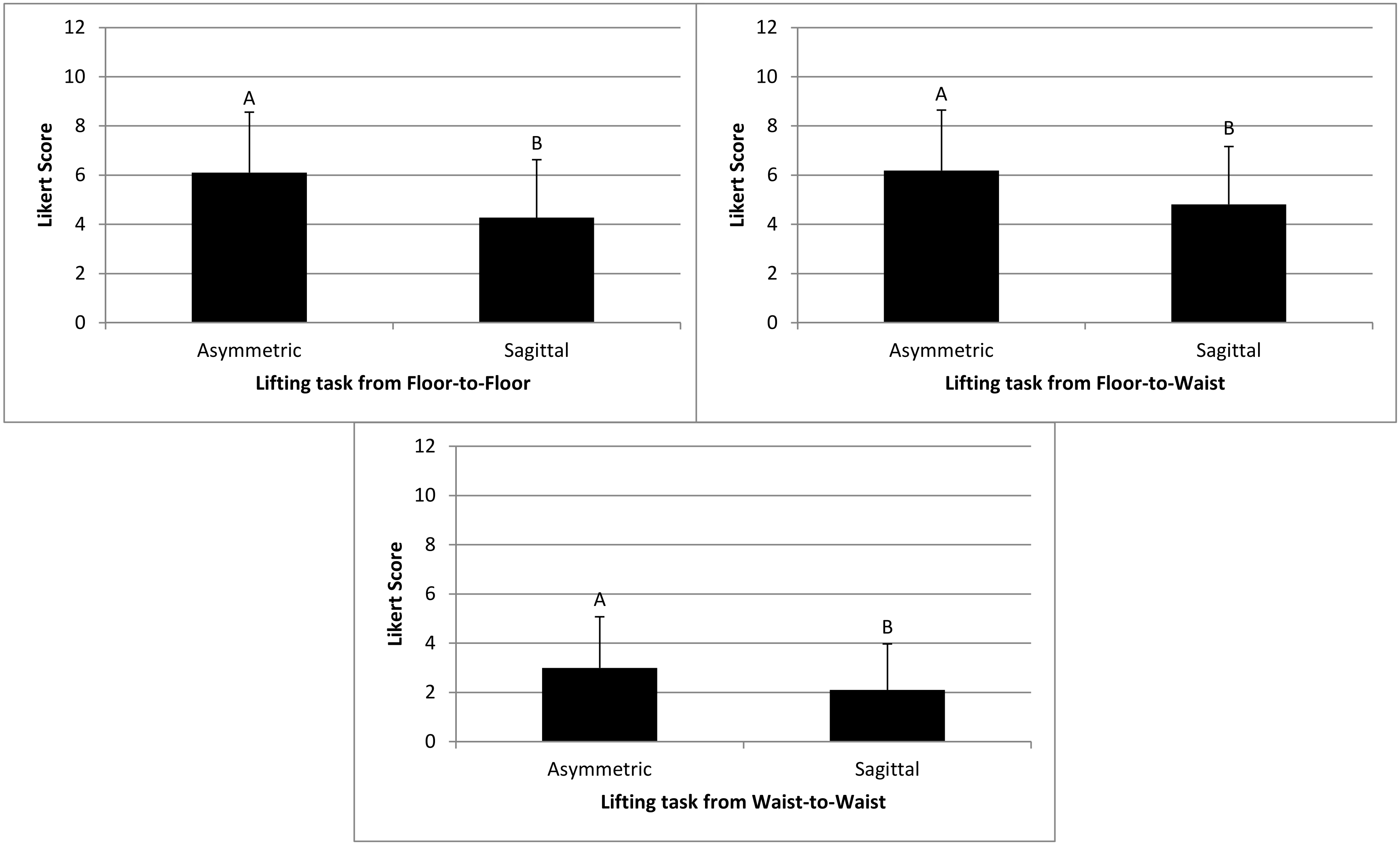


Figure 4.7 Column plots for the Asymmetric vs. Sagittal two way ANOVA. Means and one standard deviation are shown. Letters that are the same denote lifting tasks that were perceived to not be statistically different in terms of risk.

4.1.4 Lifts with Poor Coupling

There were significant interaction and main effects of coupling vs. vertical height combination on risk perception ($p<0.05$, Table 4.5, Figure 4.8). Apart from lifting from the floor to the floor, coupling was perceived to not be significantly different than lifting with good coupling (Figure 4.9). Additionally, in the poor coupling group, the lifting video that began and ended at the floor was rated higher than the floor-to-waist lift. The opposite was true for lifts with good coupling. However, for both lifting conditions, lifts starting at the waist were rated significantly lower than the lifts starting at the floor.

Table 4.5 2x3 ANOVA using Coupling (Lcondn) and Lifting Height Combination (HCWords) as factors.

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	5	3151.536	630.307	132.020	<.0001
Error	2130	10169.670	4.774		
Corrected Total	2135	13321.206			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Lcondn	1	151.101	151.101	31.650	<.0001
HCWords	2	2194.094	1097.047	229.770	<.0001
Lcondn*HCWords	2	114.678	57.339	12.010	<.0001

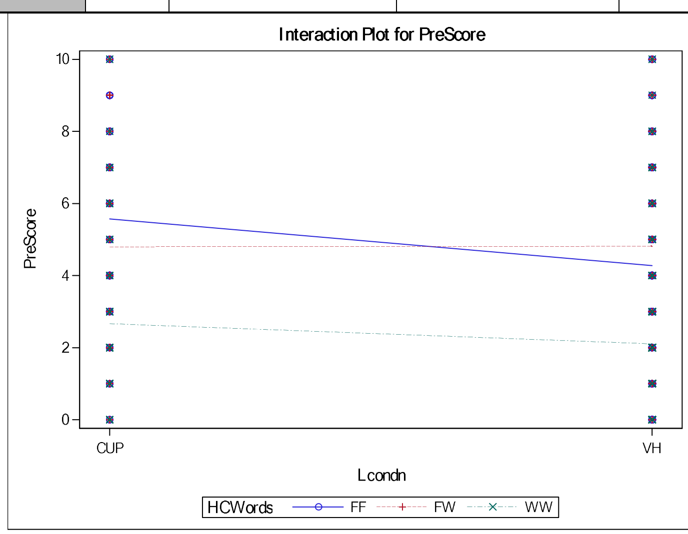


Figure 4.8 Interaction plot for 2x3 ANOVA of Good (VH)/Bad Coupling (CUP) vs. Vertical Height Combinations (HCWords). The Likert scores (PreScore) of various height combinations (HCWords) are shown for the Floor-to-Floor (FF), Floor-to-Waist (FW), and Waist-to-Waist (WW).

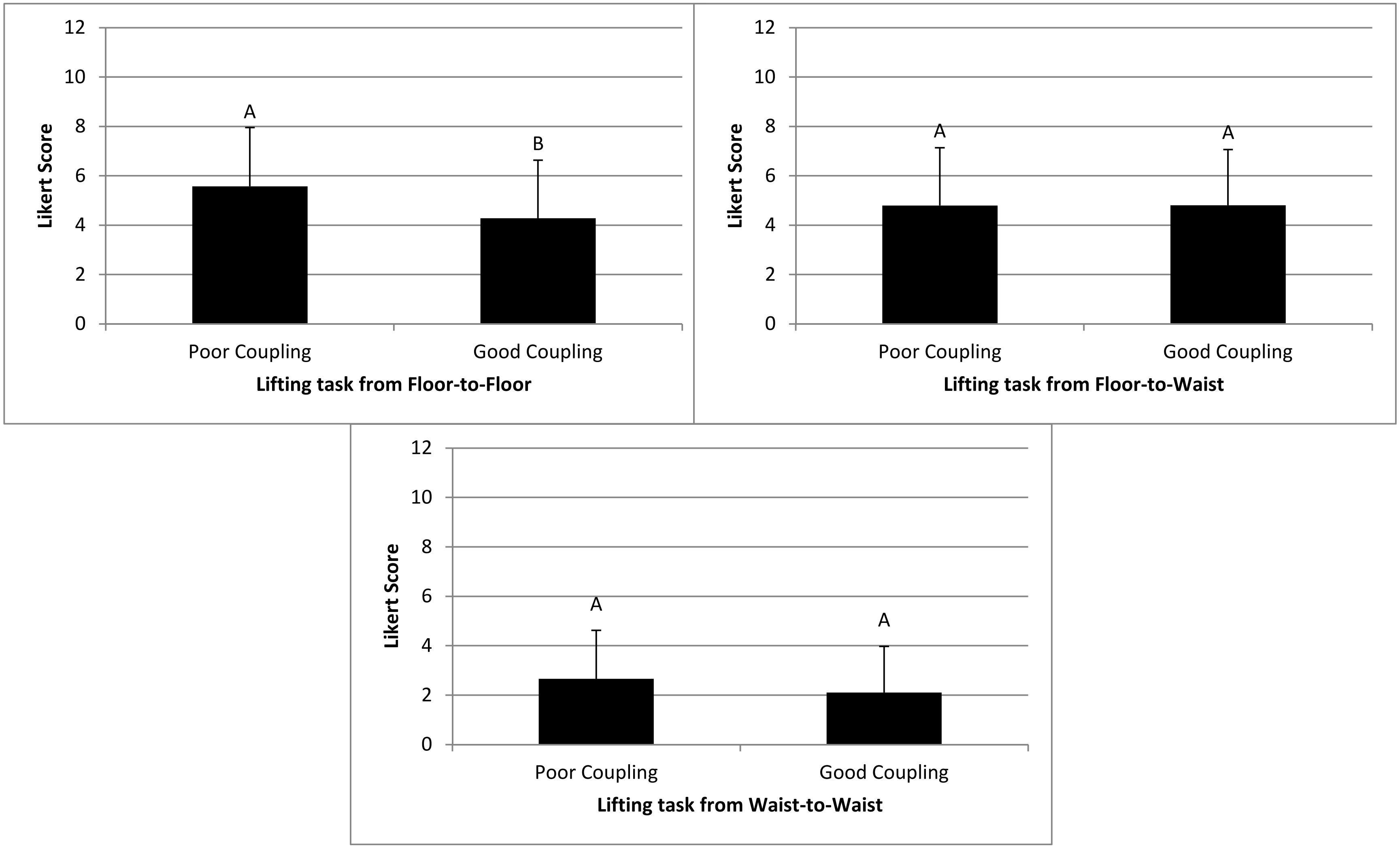


Figure 4.9 Column plots for the Poor/Good Coupling vs. Vertical Height two way ANOVA. Means and one standard deviation are shown. Letters that are the same denote lifting tasks that were perceived to not be statistically different in terms of risk.

4.1.5 Repetitive/Frequent Lifts

There were significant interaction effects of repetition (FREQ) vs. height combination on risk perception ($p<0.05$, Table 4.6, Figure 4.11). For lifts originating from the floor, the repeated lift ratings were not significantly different from the single instance lifts; however, at the waist level, participants rated the repeated lifts to be significantly riskier than the single instance lift (Figure 4.11).

Table 4.6 2x3 ANOVA using Frequency (Lcondn) and Lifting Height Combination (HCWords) as factors.

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	5	2389.398	477.880	98.270	<.0001
Error	2130	10358.260	4.863		
Corrected Total	2135	12747.659			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Lcondn	1	0.316	0.316	0.060	0.7988
HCWords	2	1265.209	632.604	130.080	<.0001
Lcondn*HCWords	2	126.535	63.267	13.010	<.0001

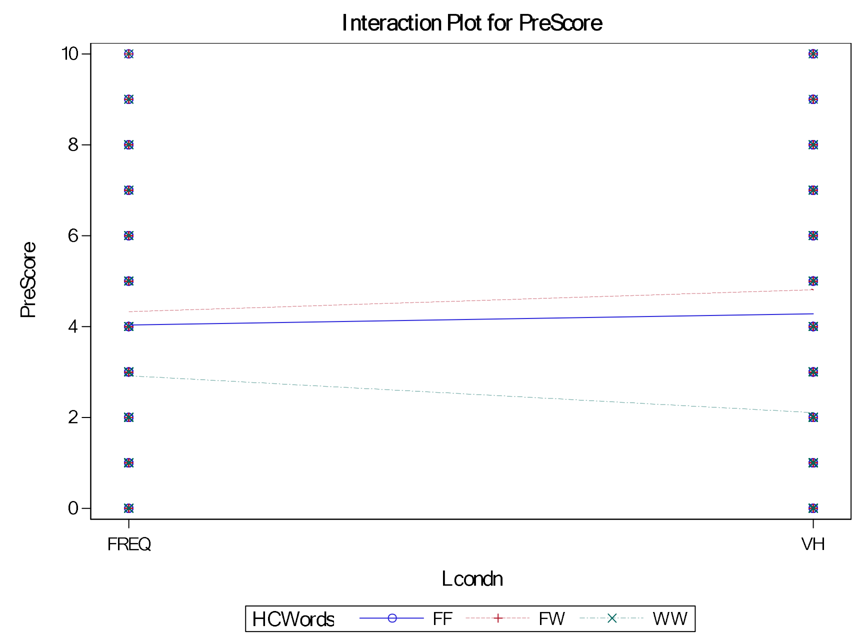


Figure 4.10 Interaction plot for 2x3 ANOVA of Repeated (FREQ)/Single (VH) Lifts vs. Vertical Height Combinations (HCWords). The Likert scores (PreScore) of various height combinations (HCWords) are shown for the Floor-to-Floor (FF), Floor-to-Waist (FW), and Waist-to-Waist (WW).

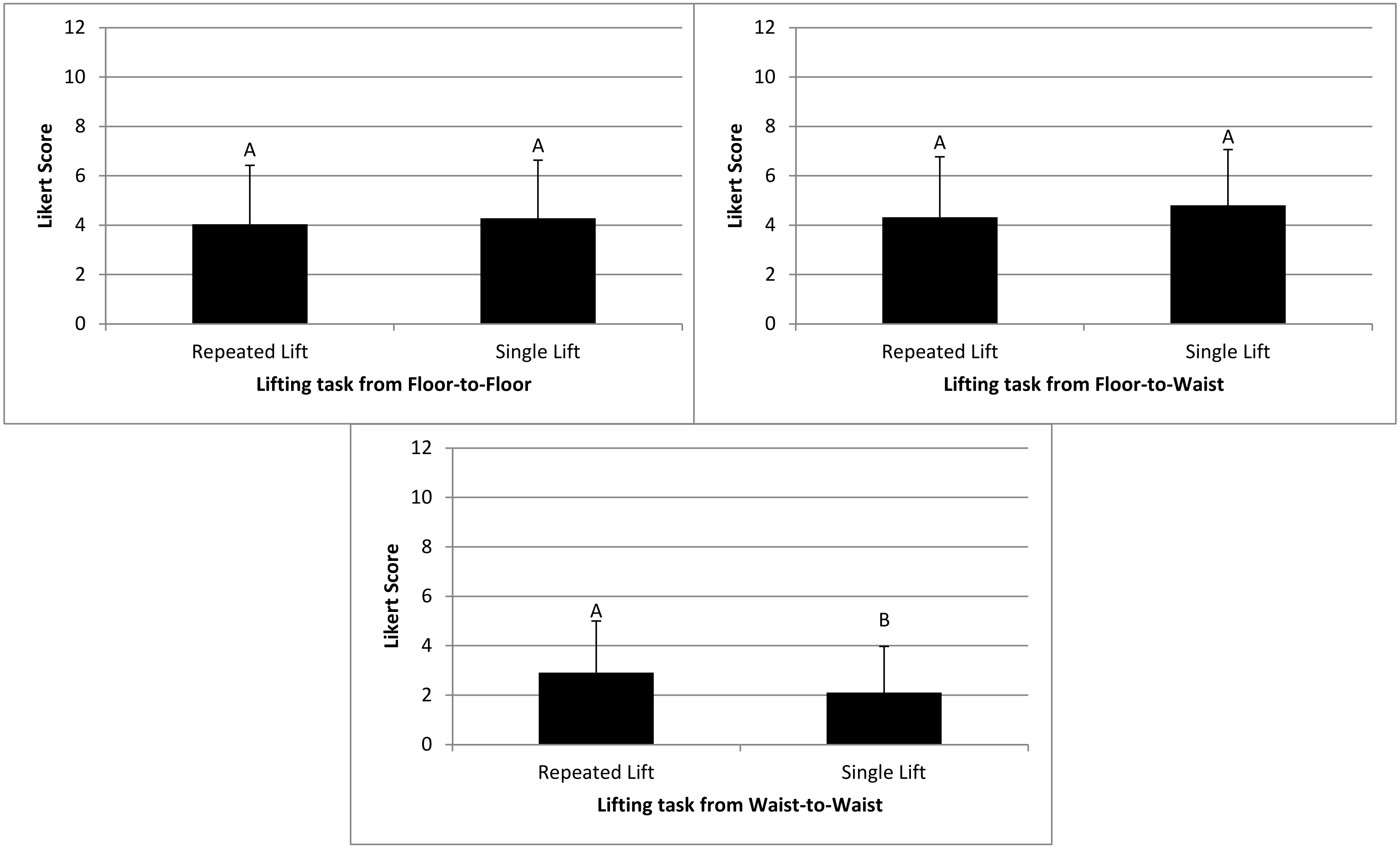


Figure 4.11 Column plots for the Repeated/Single lifts and Vertical Height two way ANOVA. Means and one standard deviation are shown. Letters that are the same denote lifting tasks that were perceived to not be statistically different in terms of risk.

4.1.6 Lifts Requiring Reach

There were significant interaction and main effects of horizontal distance vs. vertical height combination on risk perception (p<0.05, Table 4.7, Figure 4.12). Apart from the lifts that start and end at the floor, the far lifts were rated significantly higher than near lifts (Figure 4.13). For both lifting conditions, videos of lifts starting at the floor were rated higher than lifts starting at the waist. Further, the lift starting at the floor and ending at the waist (increased travel in vertical distance) was rated higher than the lift that started and ended at the floor.

Table 4.7 2x3 ANOVA using Horizontal Reach (Lcondn) and Lifting Height Combination (HCWords) as factors.

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	5	3540.005	708.001	150.050	<.0001
Error	2130	10050.463	4.719		
Corrected Total	2135	13590.468			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Lcondn	1	273.147	273.147	57.890	<.0001
HCWords	2	2627.248	1313.624	278.400	<.0001
Lcondn*HCWords	2	81.158	40.579	8.600	0.0002

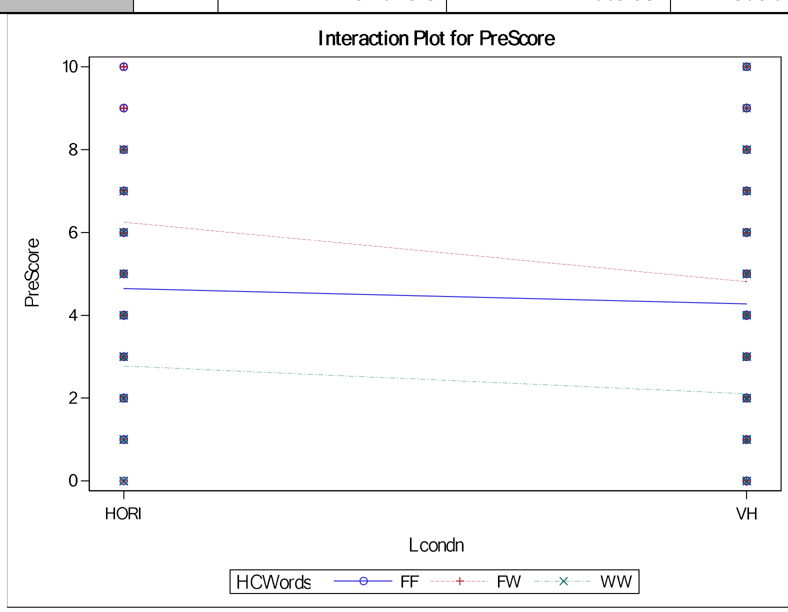


Figure 4.12 Interaction plot for 2x3 ANOVA of Far (HORI)/Near (VH) Lifts vs. Vertical Height Combinations (HCWords). The Likert scores (PreScore) of various height combinations (HCWords) are shown for the Floor-to-Floor (FF), Floor-to-Waist (FW), and Waist-to-Waist (WW).

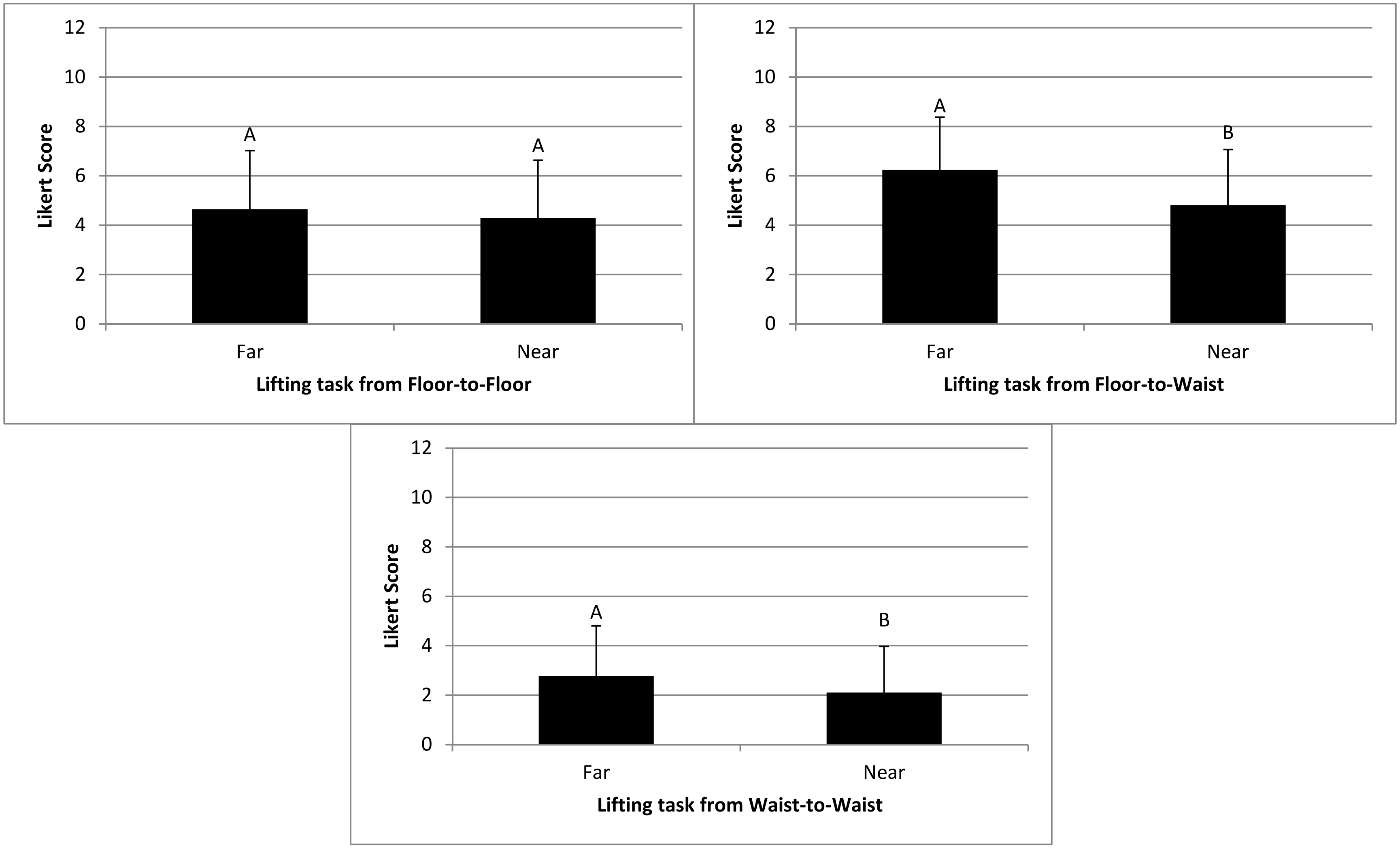


Figure 4.13 Column plots for the Far/Near lifts and Vertical Height two way ANOVA. Means and one standard deviation are shown. Letters that are the same denote lifting tasks that were perceived to not be statistically different in terms of risk.

4.1.7 Lifting Technique

There was no interaction effect of lifting technique vs. vertical lifting height (p=0.0577, Table 4.8, Figure 4.14); however, there were main effects of both lifting technique and vertical lifting height (p<0.05, Table 4.8). The post hoc test results showed that stooping was perceived to be riskier than squat lifting (p<.0001, Figure 4.15, Appendix B: Table 9.14). Additionally, it was seen that stoop lifts originating from the floor height were also perceived to be riskier than lifts originating from the knee height (p=0.0198, Appendix B: Table 9.14, Figure 4.15). On average, the stoop lift was rated up to 2.9 Likert units higher (or 60% higher) than the corresponding squat lift (Appendix B: Table 9.14).

Table 4.8 Two Way ANOVA using Vertical Height (VH) and Stoop/Squat lifting technique (TECH) as factors.

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	3	1939.310	646.437	114.53	<.0001
Error	1420	8014.830	5.644		
Corrected Total	1423	9954.140			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
TECH	1	1868.124	1868.124	330.98	<.0001
VH	1	71.068	71.068	12.59	0.0004
TECH*VH	1	20.371	20.371	3.61	0.0577

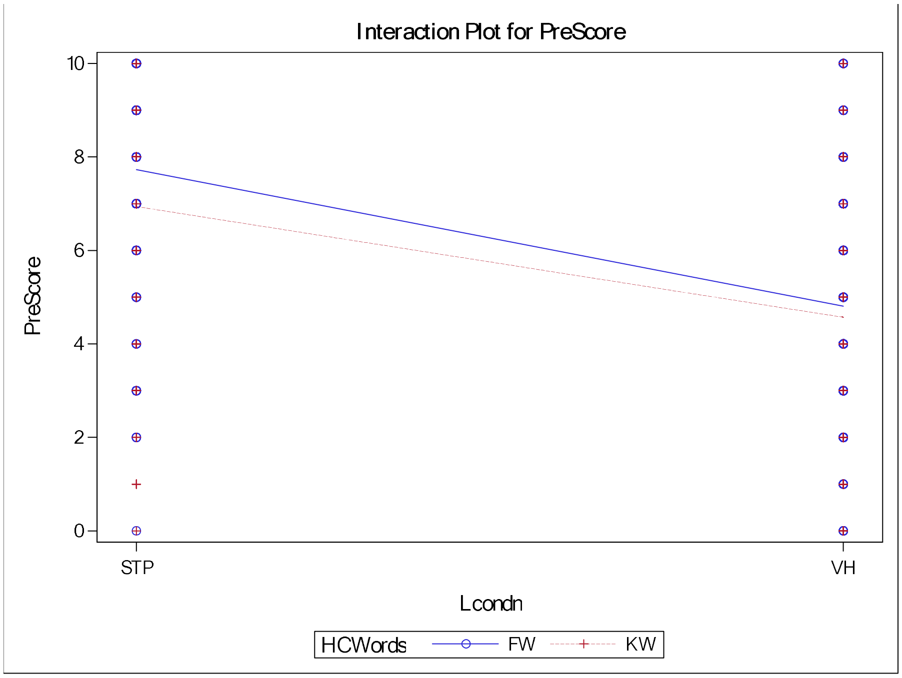


Figure 4.14 Interaction plot for 2x2 ANOVA of Squat lifting (VH) vs. Stoop Lifting (STP). The Likert scores (PreScore) of two height combinations (HCWords) are shown for the Floor-to-Waist (FW) and Knee-to-Waist (KW) lifts.

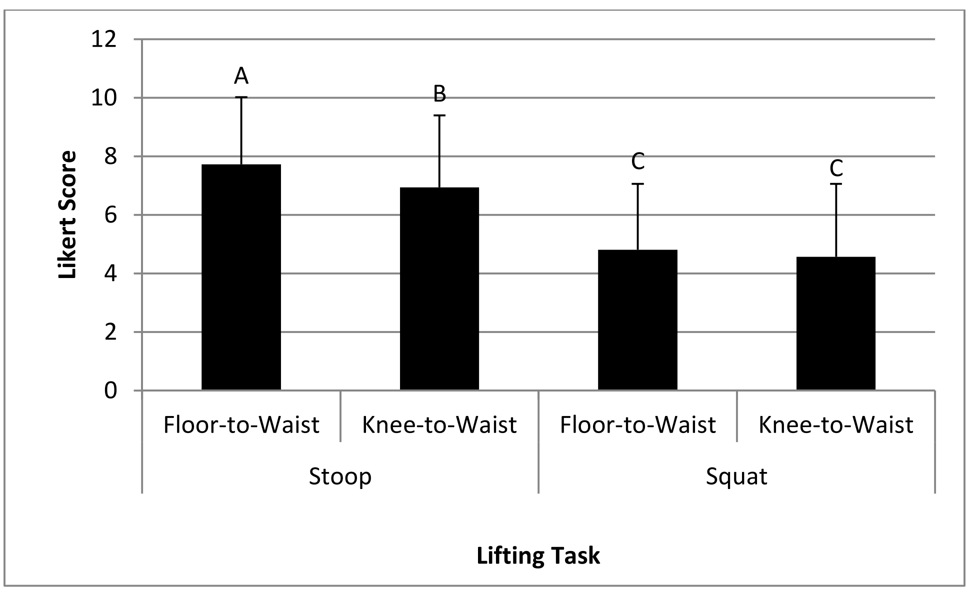


Figure 4.15 Column plot for the Stoop vs. Squat 2x2 ANOVA. Means and one standard deviation are shown. Letters that are the same denote lifting tasks that were perceived to not be statistically different in terms of risk.

4.1.8 Weight of Object

There were significant interaction and main effects of the load of the lift (WEIGHTS) vs. vertical height (VH) on risk perception (*p*<.0001, Table 4.9, Figure 4.16). Depending on the lift origin, the results show that heavy loads (HEV) can be perceived to have risk greater than or equal to medium loads (VH) which in turn are both perceived to have greater risk than light loads (LIT) (Figure 4.17). On average, when perceiving lifts in a higher weight category, Likert scores would increase by about 2 units (LIT mean = 2.03, VH mean = 4.36, HEV mean = 6.18, Appendix B: Table 9.15).

Table 4.9 Two Way ANOVA using Vertical Height (VH) and Load of Lift (WEIGHTS) as factors.

Source	**DF**	**Sum of Squares**	**Mean Square**	**F Value**	**Pr > F**
Model	14	12614.917	901.066	186.52	<.0001
Error	4079	19705.129	4.831		
Corrected Total	4093	32320.046			
Source	DF	Type III SS	Mean Square	F Value	Pr > F
Lcondn	2	7727.220	3863.610	799.77	<.0001
HCWords	4	3273.717	818.429	169.42	<.0001
Lcondn*HCWords	8	782.814	97.852	20.26	<.0001

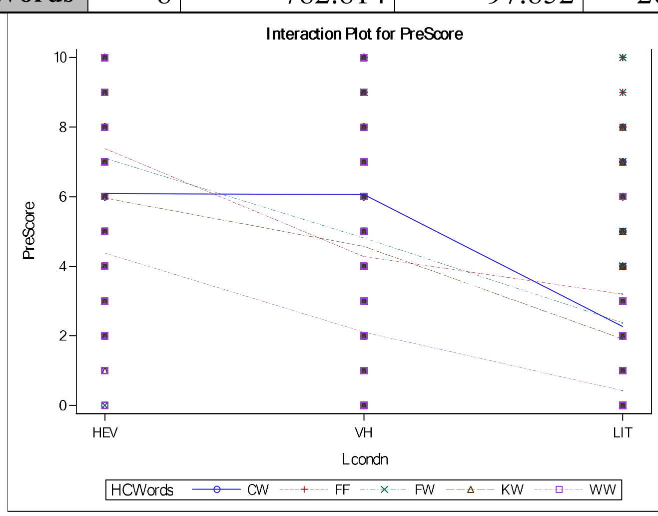
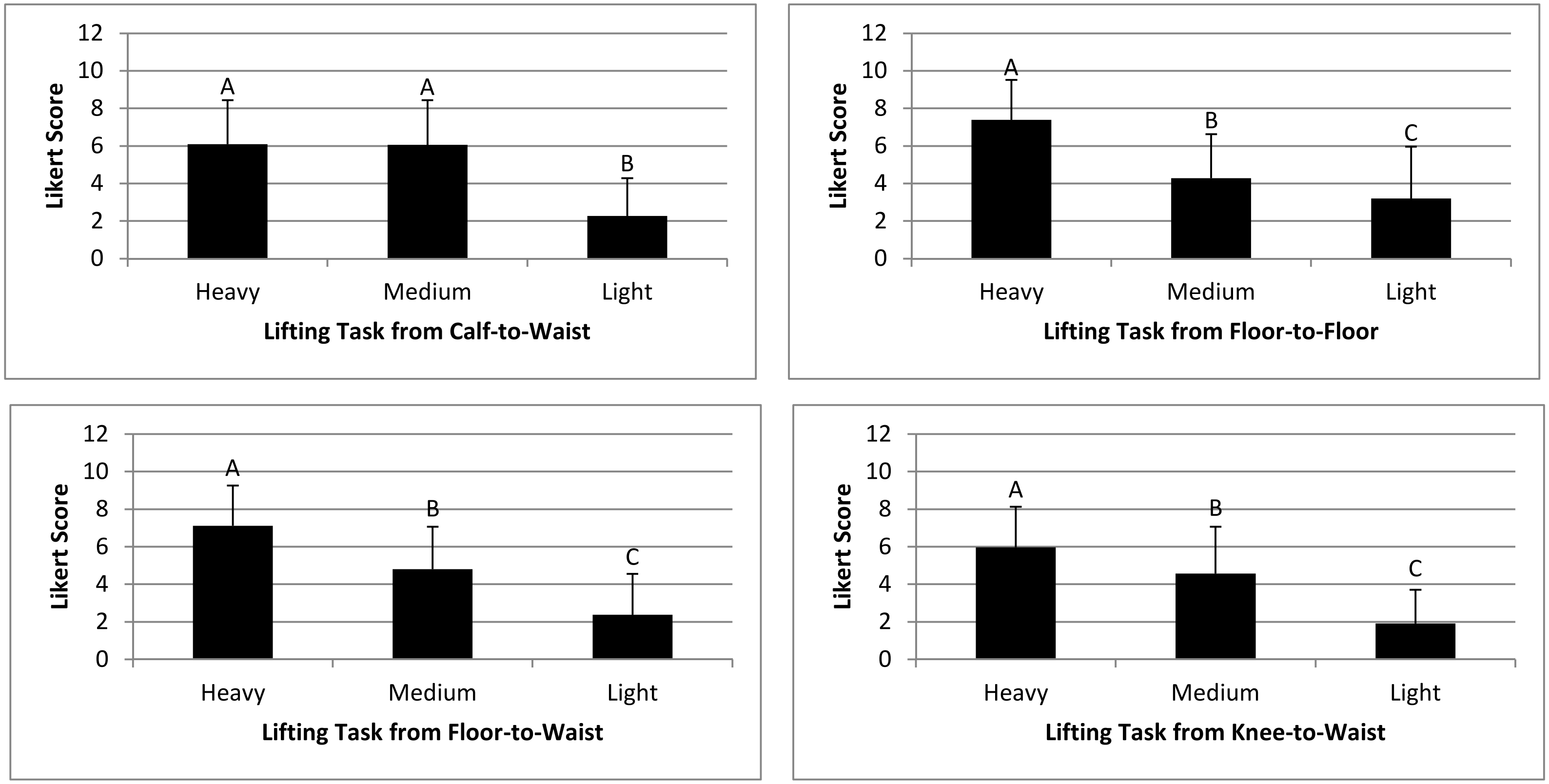


Figure 4.16 Interaction plot for 5x3 ANOVA of Height Combinations (HCWords) vs. Object Weights. The Likert scores (PreScore) of Light (LIT), Medium (VH), and Heavy (HEV) lifting tasks for five height combinations (HCWords) are shown for the Calf-to-Waist (CW), Floor-to-Floor (FF), Floor-to-Waist (FW), Knee-to-Waist (KW), and Waist-to-Waist (WW) lifts.



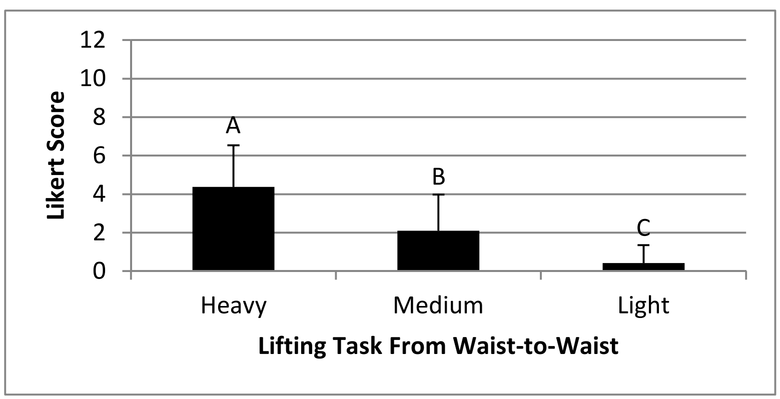


Figure 4.17 Column plots for the Object weights at five different height combinations. Means and one standard deviation are shown. Letters that are the same denote lifting tasks that were perceived to not be statistically different in terms of risk.

4.1.9 Use of a Back Belt

There was a significant effect of back belt on risk perception (p<.0001, Table 4.10). Wearing a back belt was perceived to be significantly less risky than performing a lift without a back belt (Figure 4.18). On average, the lifting with back belt video received a Likert score that was lower than the lifting without back belt videos by 0.9 Likert units (i.e. using a back belt was perceived to be almost 19% less risky than lifting without one) (Table 4.11).

Table 4.10 One way ANOVA using Back Belt as a factor.

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	1	110.579	110.579	21.94	<.0001
Error	710	3578.697	5.040		
Corrected Total	711	3689.275			

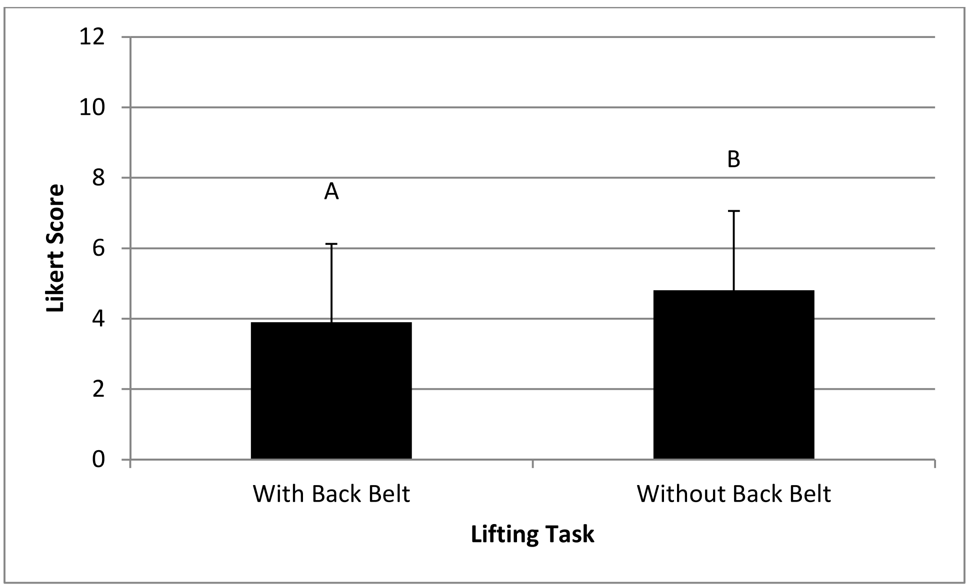


Figure 4.18 Column plot for Back Belt. Means and one standard deviation are shown. Letters that are the same denote lifting tasks that were perceived to not be statistically different in terms of risk.

Table 4.11 One way ANOVA for Back Belt: Descriptive Statistics.

Name of Task	N	Mean	STDEV
BB FW	178	3.899	2.222
VH FW	534	4.809	2.253

4.2 Message Efficacy

Both messages had significant effects on Likert rating scores. A Bonferroni correction was used in an attempt to decrease type I error and to adjust for multiple comparisons. This correction led to an adjusted α value of 0.000694. The results are organized by lifting height origin/destination combinations, lifting factor, and whether they received the back belt or lifting height message (Figure 4.20 and Figure 4.21 respectively). For more interpretability, a concise table showing only the significant percentage changes from the pre Likert score is shown in Table 4.12 (Full table can be found in Appendix B: Table 9.17). Risk perception percentage change was calculated by taking the difference between Post and Pre Likert rating scores and showing the difference as a percentage of the Pre score. Since the focus of this thesis was to increase recognition of vertical height (VH) as a risk factor, Figure 4.19 illustrates the effect of the messages for only the VH videos.

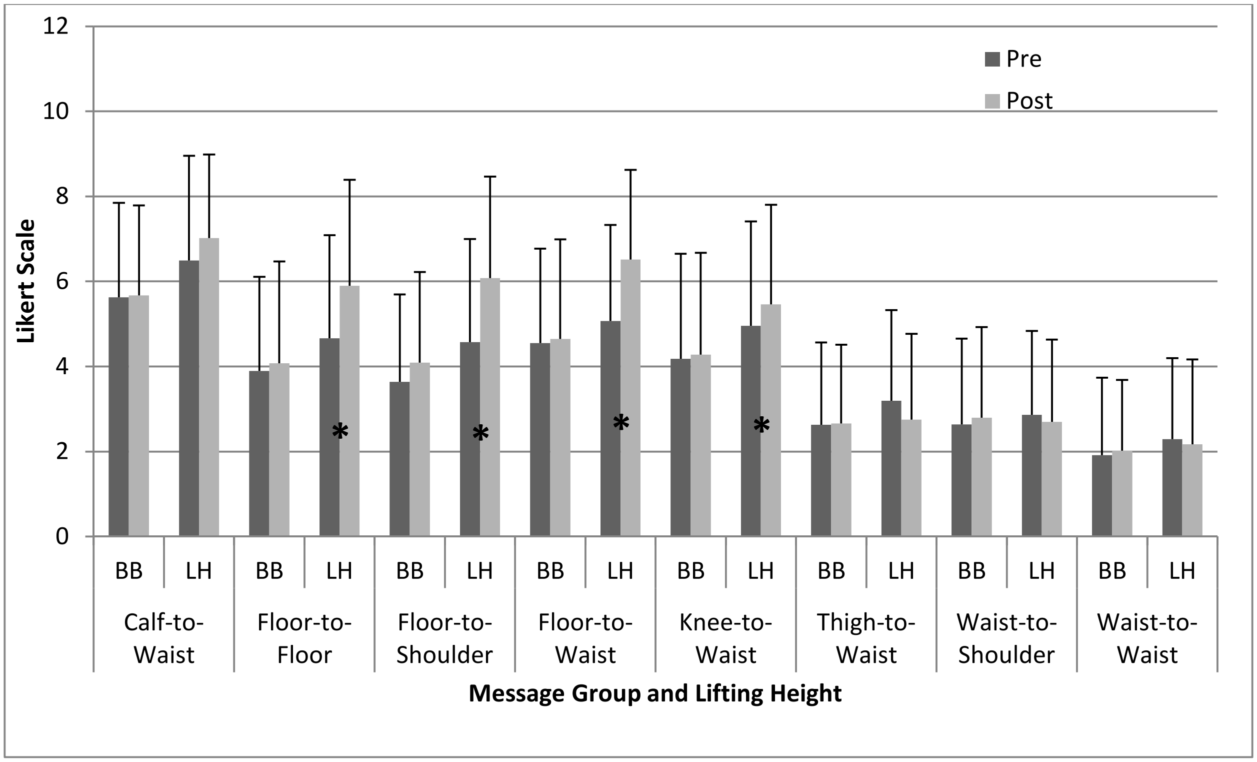


Figure 4.19 Pre and Post mean Likert scores with 1 standard deviation for Back Belt message group (BB) vs. Lifting Height message group (LH). *'s denote significant difference (adjusted p<0.05).

In the group that received the lifting height message, the risk perceptions for 19 of the 36 types of lifts were significantly changed (adjusted p<0.05). Of the 19 significant changes, the lifting height message seemed to increase risk perception of 18 of the tasks and decrease risk perception of 1 of the tasks. Tasks originating from the floor, calf, and knee were perceived to be 9% to 60% riskier post lifting height message (mean Likert increases ranged from 0.51 up to 2.15 units) (adjusted p<0.05). Conversely, the KW Heavy task was perceived to be 11% less risky after having read the lifting height message (mean Likert decreases ranged by 0.69 units) (adjusted p<0.05). Although not statistically significant, three other tasks also showed a decrease in risk perception (the TW default, WW Heavy, and WW Horizontal reach lifts).

On the other hand, for the group that received the back belt message, the risk perceptions for 3 of the 36 types of lifts were significantly changed (adjusted $p<0.05$). Post educational message, the back belt message group rated the lifting with a back belt video closer to the lifting without back belt videos; there was a difference of only 0.3 Likert units. Aside from the back belt video, the back belt message seemed to also increase risk perception of 2 other tasks. This message had an indiscriminate effect on tasks and increased risk perception by 20% to 28% (mean Likert increases ranged from 0.71 up to 0.88 units) (adjusted $p<0.05$).

Using the 3DMatch compression values as a standard (estimated risk), a Pearson Product Moment Correlation was run on estimated risk and perceived risk (participant ratings). The correlation was performed on the Lifting Height message group Pre and Post ratings. Correlations with 3DMatch increased post educational message (R-value increased from 0.509 Pre message to 0.577 Post message, $p<0.0001$).

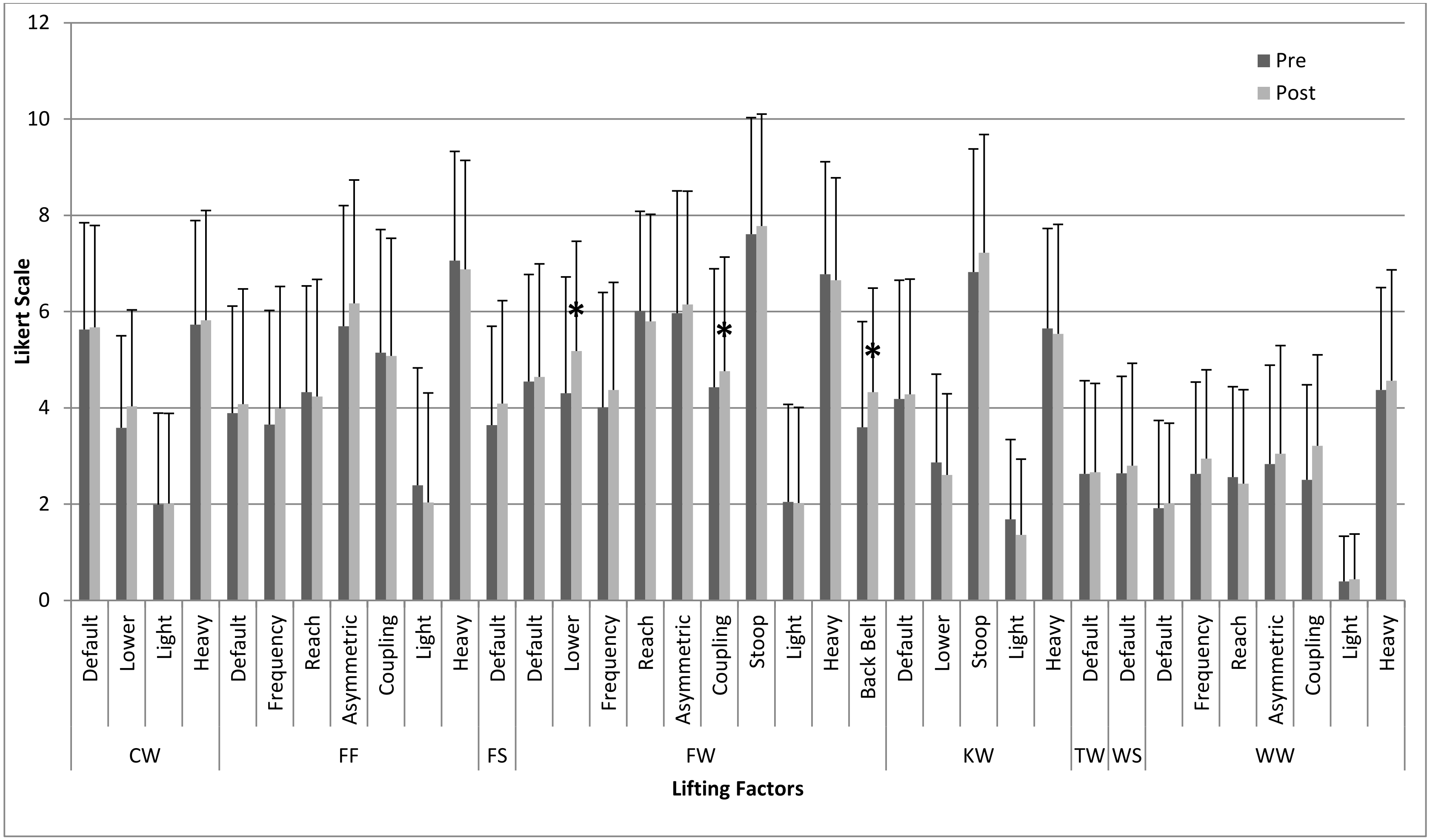


Figure 4.20 Pre and post mean Likert scores with 1 standard deviation for the Back Belt message group. *'s denote significant difference (adjusted $p<0.05$). 8 lifting height combinations are shown with up to 10 manipulated lifting factors are shown. The lifting height combinations are from Calf-to-Waist (CW), Floor-to-Floor (FF), Floor-to-Shoulder (FS), Floor-to-Waist (FW), Knee-to-Waist (KW), Thigh-to-Waist (TW), Waist-to-Shoulder (WS), and Waist-to-Waist (WW).

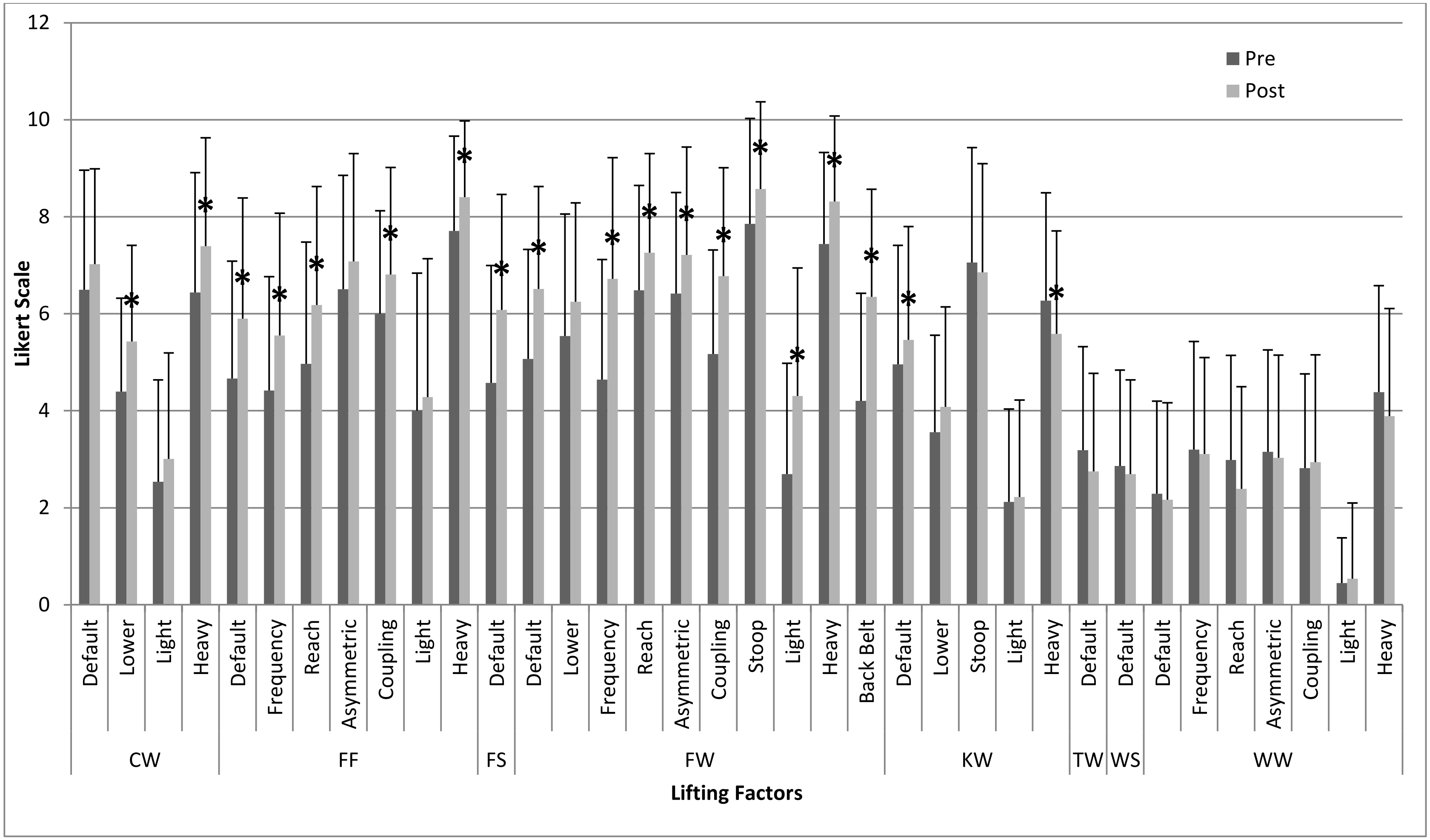


Figure 4.21 Pre and post mean Likert scores with 1 standard deviation for the Lifting Height message group. *'s denote significant difference (adjusted *p*<0.05). 8 lifting height combinations are shown with up to 10 manipulated lifting factors are shown. The lifting height combinations are from Calf-to-Waist (CW), Floor-to-Floor (FF), Floor-to-Shoulder (FS), Floor-to-Waist (FW), Knee-to-Waist (KW), Thigh-to-Waist (TW), Waist-to-Shoulder (WS), and Waist-to-Waist (WW).

Table 4.12 Average Post-Pre percent differences. N is the number of trials and SD is the standard deviation of each score. ↑'s denote a significant increase in risk perception while ↓'s denote a significant decrease in risk perception (adjusted $p<0.05$). C=Calf, W=Waist, F=Floor, S=Shoulder, K=Knee, T=Thigh. So CW=a lift from calf to waist height. N=267 denotes tasks with multiple videos.

		Back Belt Message					Lifting Height Message				
HCWords	Lcondn	N	Mean	STDEV	p-value	% Change from Pre	N	Mean	STDEV	p-value	% Change from Pre
CW	HEV						89	0.955	2.205	<.0001	15% ↑
	LOW						89	1.034	1.715	<.0001	24% ↑
FF	CUP						89	0.809	1.870	<.0001	13% ↑
	FREQ						89	1.135	1.990	<.0001	26% ↑
	HEV						89	0.697	1.555	<.0001	9% ↑
	HORI						89	1.214	1.806	<.0001	24% ↑
	VH						267	1.236	2.059	<.0001	27% ↑
FS	VH						89	1.506	1.829	<.0001	33% ↑
FW	ASY						89	0.798	1.646	<.0001	19% ↑
	BB	89	0.730	1.536	<.0001	20% ↑	89	2.146	2.135	<.0001	33% ↑
	CUP						89	1.607	1.723	<.0001	31% ↑
	FREQ						89	2.079	2.283	<.0001	45% ↑
	HEV						89	0.876	1.698	<.0001	12% ↑
	HORI						89	0.775	1.643	<.0001	12% ↑
	LIT						89	1.607	2.329	<.0001	60% ↑
	LOW	89	0.876	2.088	0.0002	20% ↑					
	STP						89	0.719	1.624	<.0001	9% ↑
	VH						267	1.442	1.947	<.0001	28% ↑
KW	HEV						89	-0.685	1.628	0.0001	-11% ↓
	VH						267	0.506	2.027	<.0001	10% ↑
WW	CUP	89	0.708	1.502	<.0001	28% ↑					

4.3 Assessing Risk Using 3DMatch

Risk of each lift was assessed using a 3D static posture analysis tool called 3DMatch. The phases at which maximal spinal loading occurred are shown in Table 4.13 below (For full table, go to Appendix B: Table 9.18). Overall, when normalized to their respective action limits, compression was the riskier of the two spinal loading mechanisms. Additionally, the phase at which each lift created the greatest amount of compression was generally when the task was at its lowest height. Further, tasks involving reaching, twisting, or a heavier weight created greater compression values than their default counterparts.

Table 4.13 Peak raw and normalized spinal loading outputs for all 44 lifting videos.

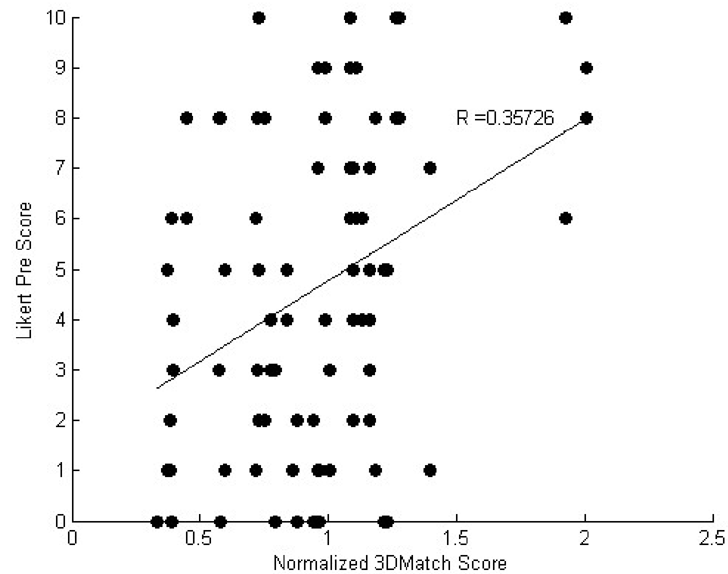
Weight	Name of Task	Frame	Joint Compression (N)	Joint A/P Shear (N)	Normalized Compression	Normalized Shear
Heavy	FW lift	Lift-Off	6544	-106.603	1.925**	-0.213
	CW lift	Mid 1	4756	-269.251	1.399**	-0.539
	FF lift	Lift-Off, Mid 1 & 4	6817	-102.408	2.005**	-0.205
	KW lift	Lift-Off	3848	-31.829	1.132**	-0.064
	WW lift	Lift-Off, End	1518	106.705	0.446**	0.213
Light	CW lift	Lift-Off	2444	-188.937	0.719**	-0.378
	FF lift	Lift-Off, Mid, End	2690	-167.949	0.791**	-0.336
	FW lift	Lift-Off	2936	-214.776	0.864**	-0.430
	KW lift	Lift-Off	1959	-72.009	0.576**	-0.144
	WW lift	End	1117	28.177	0.329**	0.056
Medium	CW lift	Lift-Off	3956	-146.085	1.163**	-0.292
	Asymmetric, FF lift	End	4336	-216.614	1.275**	-0.433
	FF Lift	Lift-Off	4186	-132.768	1.231**	-0.266
	Coupling, FF Lift	Lift-Off, End	3779	-232.260	1.112**	-0.465
	Frequency, FF lift	Lift-Off 1-4, End 1-4	2487	-43.781	0.732**	-0.088
	Reach, FF lift	Lift-Off	4015	-113.687	1.181**	-0.227
	FF lift	Lift-Off, Mid 1, End	3269	-157.463	0.962**	-0.315
	FF lift	End	3361	-155.890	0.989**	-0.312
	FS lift	Lift-Off	3423	-154.841	1.007**	-0.310
	FW lift	Lift-Off	3729	-149.755	1.097**	-0.300
	Asymmetric, FW lift	Lift-Off	3691	-230.516	1.086**	-0.461
	Back Belt, FW lift	Lift-Off	3283	-164.634	0.966**	-0.329
	Coupling, FW lift	Lift-Off	3722	-236.211	1.095**	-0.472
	Frequency, FW lift	Lift-Off 1-4	2644	-210.780	0.778**	-0.422
	Reach, FW lift	Lift-Off	3695	-157.713	1.087**	-0.315
	FW lift	Lift-Off	3205	-220.575	0.943**	-0.441

Stoop, FW lift	Mid	3696	-171.688	1.087**	-0.343
FW lift	Lift-Off, Mid	3954	-146.111	1.163**	-0.292
KW lift	Lift-Off	2487	-43.781	0.732**	-0.088
KW lift	Lift-Off, Mid	2844	-26.979	0.836**	-0.054
Stoop, KW lift	Lift-Off, Mid	4307	-130.281	1.267**	-0.261
KW lift	Mid	3954	-146.111	1.163**	-0.292
TW lift	Lift-Off	2553	-55.389	0.751**	-0.111
WC Lower	End	3350	-150.749	0.985**	-0.302
WF Lower	End	4137	-133.801	1.217**	-0.268
WK Lower	End	3252	-152.968	0.956**	-0.306
WS lift	End	1335	79.010	0.393**	0.158
WW lift	End	1311	74.668	0.385**	0.149
Asymmetric WW lift	Lift-Off	1951	-91.166	0.574**	-0.182
WW lift	End	1321	76.561	0.389**	0.153
Coupling, WW lift	Lift-Off	2994	-20.258	0.881**	-0.041
Frequency, WW lift	End 3	1260	65.144	0.371**	0.130
Reach, WW lift	Lift-Off	2451	-40.473	0.721**	-0.081
WW lift	End	2024	-77.827	0.595**	-0.156

** denotes the number taken as the maximum normalized risk value for each lifting task

4.4 How Demographics Affect Risk Factor Recognition Abilities

Using the values above as a standard, participant Pre Likert scores were correlated to the 3DMatch normalized compression values. An overall Pearson Product Moment Correlation was run between 3DMatch and participant ratings and a significant R-value of 0.495 was found (p<.0001). Additional significant correlations were seen between risk perception and biomechanically estimated risk among the demographically stratified groups (7 groups) (p<0.05). After using a Bonferroni correction to adjust for multiple correlations, all but 3 of the correlation R-values were statistically significant, positive, and their magnitudes ranged from 0.357 to 0.674 (p<0.05, Figure 4.22,Table 4.15, Appendix B: Table 9.19).



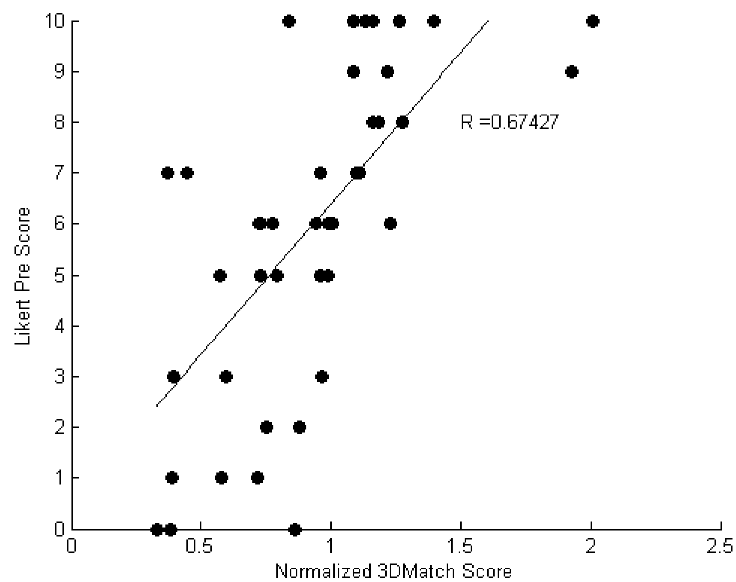


Figure 4.22 Scatter plots of the lowest (top: Trade Sector group, N=2) and highest (bottom: Employer & Health & Safety Representative role group, N=1) correlation R-values.

The results show that males (R=0.526) correlated slightly better with 3DMatch risk values than females (R=0.472) (Table 4.15). When investigating correlations by the position(s) participants held in companies, the results show that employers who were also the health & safety representative (R=0.674) correlated most with 3DMatch, while supervisors who were also the health and safety representative (R=0.440) correlated least. When participants were stratified by self-reported scores of familiarity of ergonomics, participants reporting a score of 0 correlated least with 3DMatch (R=0.389) while participants reporting a score of 1 correlated best with 3DMatch (R=0.588). In terms of sector, participants who reported that they worked in the Finance, insurance, real estate and leasing sector correlated best with 3DMatch (R=0.628). In contrast, participants who reported working in the Trade sector correlated least (R=0.357). Additionally, participants who had been working in their sector for less than 1 year correlated best with 3DMatch (R=0.538) while participants who have worked for 10 years or more correlated least (R=0.451). Participants reporting that they had suffered a low back injury that resulted in lost work time within the past 5 years had an R value of 0.554, which was higher than the group who reported having suffered a low back injury in the past 6 months (R=0.397). Lastly, participants reporting that they worked in a business that employed between 20 and 50 individuals had an R-value of 0.600, which was higher than the participants who did not specify the size of the business they worked for (R=0.376).

Although there were some outlying high and low correlation scores, the majority of the R-values calculated ranged from 0.45 to 0.55 (Figure 4.23).

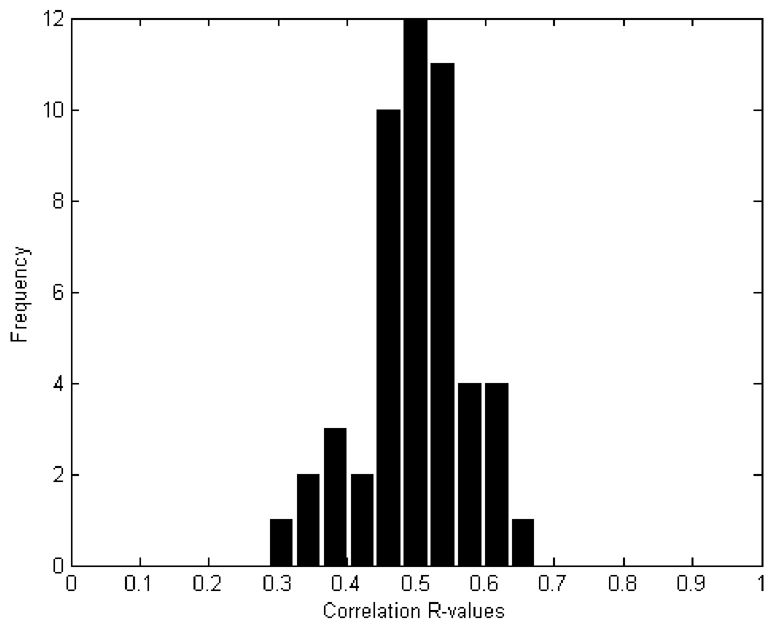


Figure 4.23 Histogram of correlation scores binned into 0.05 score intervals.

All groups correlated positively with 3DMatch, meaning that as 3DMatch scores increased, the participant Likert ratings increased as well. However, the magnitudes of these R-values suggest a weak to moderate (strong in a few cases) linear relationship. Overall, there did not seem to be any demographic factor that could predict a group of people who could correlate strongly with 3DMatch.

To investigate why the ergonomic familiarity categorization did not behave as expected, post-collection, 3 more participants were asked to perform the survey to assemble a group of 6 low back experts (Ph.D. candidates in Biomechanics who specialized in low back issues). Pearson Product Moment Correlation scores were calculated and their R-values were (with familiarity scores in brackets) 0.460 (5), 0.773 (4), 0.710 (4), 0.625(3) 0.738(5), 0.593(5).

Additionally, to examine why there were no strong R-values, the rank of the FW Stoop video was calculated for both 3DMatch and the participants. When translated into ranked scores, 3DMatch ranked the FW Stoop task at 29th out of 44 tasks while the average participant ranked the task somewhere between 38th/39th out of 44 tasks. In contrast, when compared to the FW tasks, 3DMatch placed the stooping task between the default lifts while the participants, on average, believed the stooping task to be riskier than all three default tasks.

Table 4.14 Risk scores converted into rank for 3DMatch and participants. Ranked values are out of 44 tasks. Higher ranks denote tasks that had higher Likert scores.

Lifting Task	3DMatch Rank	Participant Average Rank
FW Stoop	29	38.77
FW Task 1	31	25.08
FW Task 2	20	21.09
FW Task 3	35	31.79

Table 4.15 Concise table of Pearson Product Moment Correlation R values stratified by demographic factor. Only significant min and max R-values are displayed per demographic.

Demographic Factor	Sub-Category	Data Points	R
Sex	Male	3476	0.526**
	Female	4224	0.472*
Role in Company	Supervisor & H&S	176	0.440*
	Employer & H&S	44	0.674**
Familiarity in Ergonomics	0-Not familiar at all	308	0.389*
	1	748	0.588**
Sector	Finance, insurance, real estate and leasing	176	0.628**
	Trade	88	0.357*
Experience in Current Sector	1 year or fewer	1408	0.538**
	10 years or more	2552	0.451*
Suffered a Low Back Injury that Resulted in Lost Time	Within the last 6 months	132	0.397*
	Within the last 5 years	660	0.554**
Number of Employees in Company	More than 20 employees but fewer than 50 employees	616	0.600**
	Unspecified	132	0.376*

*'s = lowest R value within a group **'s = highest R value within a group

5. Discussion

The aim of this research was to investigate knowledge transfer and conceptual knowledge utilization in order to mitigate manual materials handling musculoskeletal disorders in work places with little to no access to safety resources. This research aims to show that using lay people in the process of recognizing risk factors for lifting, can, in fact, be part of a feasible MSD prevention strategy. The results showed that a simple educational message can change perceptions of risk. To give additional insight into what people considered risky, various lifting risk factors were shown and the resulting scores showed that these factors elicited significant effects on risk ratings. Finally, demographically stratified correlations showed that the majority of individuals significantly and positively (albeit, weakly) correlated with an industrially used risk assessment tool.

Each of the 3 investigations was examined and addressed using empirical data. To reiterate, the 3 investigations were:

1) *Significant differences of perceived risk ratings will be seen when varying lifting risk factors.*

Manipulating lifting variables produced significant interaction effects in 3 of the 6 variables and significant main effects in all 6 variables for survey participant Pre scores.

1.2 Vertical Height – Low lying lifts will have higher video rating scores than the more upright standing lifts.

Video pre scores of risk perception were significantly affected by vertical height. Lifts originating at knee height or lower were seen to be riskier than the tasks originating from the thigh and above. This hypothesis was conditionally accepted because although the height of the lift did not perfectly correlate with the amount of risk perceived, a low-lying lift threshold can be seen at the knee level.

1.3 Lifting Vs. Lowering – There will be no difference in video rating scores between lifting and lowering.

Lowering to the calf or knee heights was seen to be less risky than lifting; however, lowering to the floor is seen to be as risky as lifting from the floor. This hypothesis was partially rejected.

1.4 Asymmetry – Videos that have a twisting component will be rated higher than purely sagittal lifts.

The twisting while lifting videos were perceived to be riskier than the purely sagittal plane lift videos at all lifting height combinations. This hypothesis was accepted.

1.5 Coupling – Videos that have an object that provides poor coupling will be rated higher than equivalent lifts of objects with good coupling.

Lifts with poor coupling were perceived to be significantly riskier than lifts with good coupling when lifting something from floor-to-floor but not significantly riskier than good coupling lifts when lifting from floor-to-waist or from waist-to-waist. This hypothesis was partially accepted.

1.6 Frequency – Videos that have repetitive tasks will be rated higher than the equivalent single lift videos.

Repetitive lifts were perceived to be statistically riskier than the single lift instances when lifting from waist-to-waist but not at the other lifting height combinations. This hypothesis was partially accepted.

1.7 Horizontal Reach – Videos where lifters are required to reach will be rated higher than lifts that are near.

Far lifts were perceived to be significantly riskier than near lifts when lifting something from floor-to-waist and from waist-to-waist but not significantly riskier than near lifts when lifting from floor-to-floor. Nevertheless, on average, all far lifts were usually rated higher than their near counterparts. This hypothesis was partially accepted.

1.8 Lifting Technique – Videos where the lifter uses a stoop lift technique will be rated higher than the squat lift equivalent lifts.

Stoop lifts were rated significantly higher than their squat lift video equivalents at both height combinations. This hypothesis was accepted.

1.9 Weight of Object – Videos that have heavier objects will receive higher ratings of perceived risk than the medium and light weighted objects.

Lifts involving heavy objects were rated higher than lifts with mediums objects, which in turn were rated higher than lifts with light objects. This was true for all lifting height combinations except when lifting from calf-to-waist, where the heavy lift was perceived to be as risky as the medium lift. This hypothesis was mostly accepted.

1.10 Use of Back Belt – Videos where the subject is wearing a back belt will have higher ratings than the non-back belt wearing equivalent video.

The lifting task that had the subject wearing a back belt was rated lower than its counterpart video that did not have a back belt. This hypothesis was rejected.

2) *The educational message will increase video rating scores of low-lying lift videos post-educational message.*

Both educational messages had significant effects on some pre-post differences of risk perception. The lifting height message group saw changes ranging from -11% to +60% of Pre to Post Likert scores in 19 of 36 tasks while the back belt message group saw significant increases ranging from 20% to 28% of Pre to Post Likert scores in 3 of 36 tasks. This hypothesis was accepted for in the lifting height message group, the Post scores of 15 of the 18 lifts originating from the floor and 2 lifts originating at the calf all significantly increased from their respective Pre ratings denoting that participants viewed the tasks as having more risk than initially perceived.

3) *Influences on video rating correlations by demographic factors like work experience and familiarity in the field of ergonomics will be observed.*

Although all correlation R values were significantly positive, they ranged from weak to moderate in strength. Additionally, when looking at demographically stratified groups, it was found that there was no clear trend as to which demographic factor could determine or help predict which group of people would correlate best with 3DMatch.

5.1 Risk Perception

5.1.1 Vertical Height

Lifts starting at or below the knee height were seen to be significantly riskier than lifts starting at the thigh or waist heights. Even before the lifting height message intervention, people seemed to understand that the lower the lift, the greater the risk of injury. However, for them, the perception of heights was not very gradual. It seems if the lift was at or below the knee, then risk increased. This may or may not be a good thing. Spinal compression and shear happen as a function of spinal flexion, which, being a continuous factor, is determined partly by lifting height, which is also a continuous variable (Callaghan & McGill, 2001; Hoozemans et al., 2008). Thus, lifts at the floor should be more risky than at the calf, which, in turn, should be riskier than lifts at the knee. It could be that this threshold helps provide insight for any terms similar to "low-lying". To the participants of this survey, "the lower their hands are to the ground" basically meant if they saw that the hands were below their knees at the beginning of a lift, then the lifter had an increased risk of sustaining a low back injury. This result helps to support quicker lift assessment tools such as the ACGIH Threshold Limit Values (TLVs) for lifting that break down lifts into regions, rather than just by using a continuous lifting height variable (Russell et al., 2007).

Unexpectedly, the CW lift produced the highest rating values, followed by the tasks starting at the floor and knee. There is a chance that survey participants could have suspected horizontal reach played a part in the lift and this could have been partly due to the angle that footage was taken at. Figure 5.1 shows two stills of the CW video.

Figure 5.1 Two stills of the medium, calf-to-waist lift. On the left, the participant has coupled with the object to pull it closer to himself. On the right, the participant just began the lift.

All video lifting subjects were instructed to pull/slide the object towards them before initiating a lift (unless otherwise specified in the horizontal reach lifts). Since survey participants only viewed the video once or twice, they could have perceived that the lift began earlier than when it truly did. Further, the CW task had a sample size that was three times smaller than the FF, FW, and KW lifts; meaning that the CW task did not have the same amount of scores to dilute any outlying ratings of the video. In the histograms of Figure 5.2, it can be seen that the CW lift shows a somewhat bi-modal distribution while FW lift shows a mostly uni-modal distribution. This can be interpreted as some participants picking up on some risky attribute that others did not, thus causing the increase in their ratings compared to the majority of others who rated the CW lift in the 3-7 Likert score range.

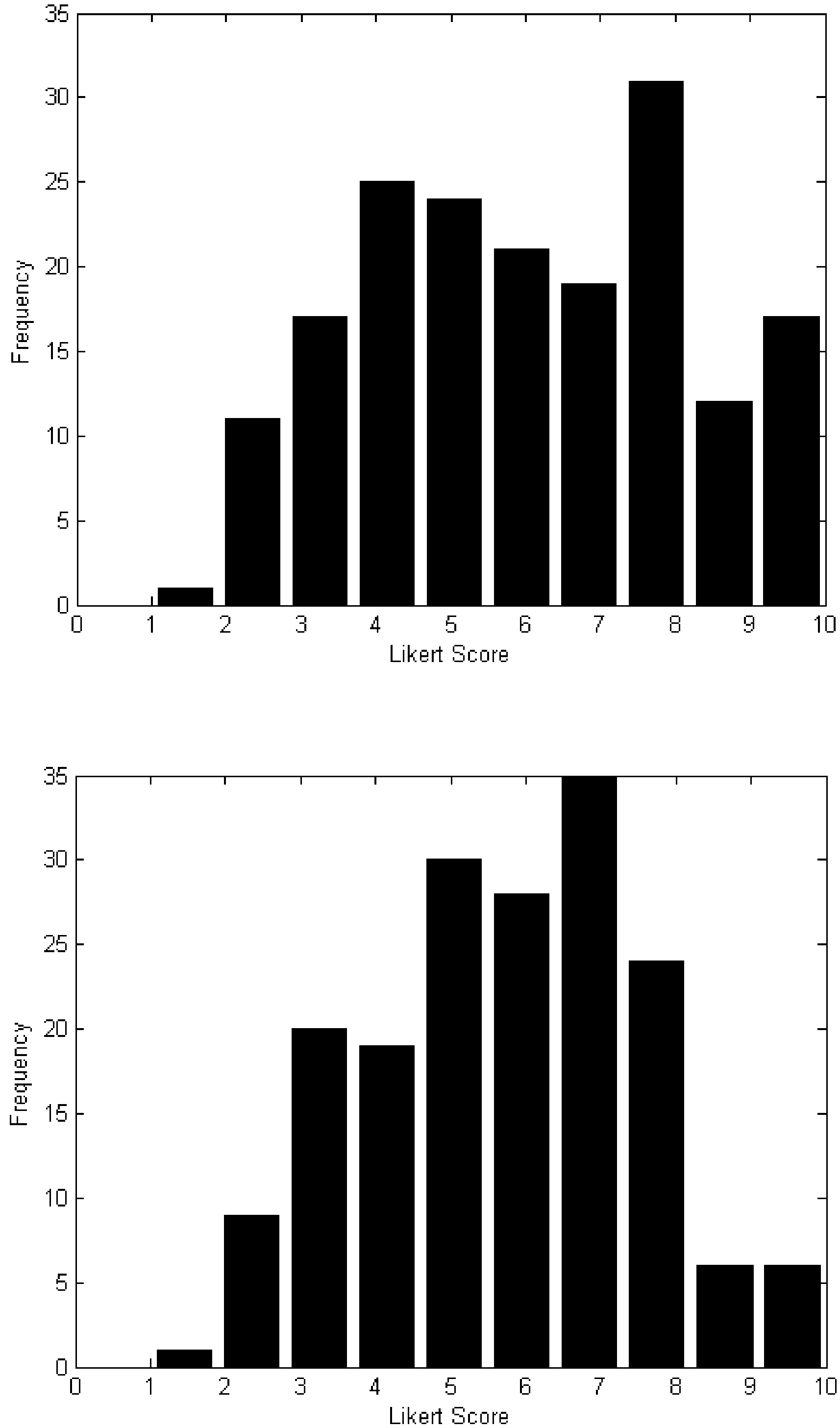


Figure 5.2 Histograms of Likert pre scores for the medium Calf-to-Waist lift (Top) and a medium Floor-to-Waist lift (Bottom).

5.1.2 Lifting vs. Lowering

Lowering was generally seen to be less risky than lifting. In an isokinetic experiment that used an EMG-assisted model, it was shown that lowering produced higher compression forces (about 600 N more) and this 600 N difference in compression was more affected by the type of task one does (lifting or lowering) than simply increasing the load by 9.1 kg (K. Davis, 1996). But, lowering produced less anterior-posterior spinal shear (about 135 N less); this difference of 135 N of shear was equivalent to decreasing the weight of the load by 9.l kg (K. Davis, 1996). Additionally, when investigating the spinal loading force per unit moment, it was found that per moment (Nm), lowering produced less compression and A/P shear than lifting. This helps support the fact that when participants lift and lower, they use different techniques; namely, when these participants lowered a weight, they increased the moment of the lift. Although there seems to be some sort of trade-off between lifting and lowering, based on this biomechanical evidence, it could be concluded that lowering produces more compression but decreases shear.

With that being said, when participants in this study rated tasks, they were only able to assess each lift through the gross kinematics of each lift. Lariviere et al. concluded that lifting and lowering had similar low back kinematics, but differing kinematics for the hip, knee, and ankle (Larivière, Gagnon, & Loisel, 2002). Additionally, a study by Seay et al. compared pelvis and trunk mechanics of healthy and low back injury participants during a lifting and lowering task and found that both groups had similar strategies for lowering but had more variable strategies for lifting (Seay, Sauer, Frykman, & Roy, 2013). This was thought to be due to the fact that lowering is simply controlling the descent of the object, while lifting required work to overcome the effects of gravity (Seay et al., 2013). Therefore, the decrease in perceived risk could be a function of thinking that it takes less work to lower an object than to raise an object.

5.1.3 Asymmetric Lifts

Of all the NIOSH variables, twisting was perceived to be riskier than pure sagittal lifts at all lifting height combinations tested. Though, the twisting videos required the object to be placed 45° to 90° away from the sagittal plane; this made the twists extreme. Work done on 3DMatch has shown that participants are able to choose between different posture bins of trunk rotation which increased in increments of 10° to 15, but more work needs to be done on how graded the perceptions are the risks of these variables (Andrews et al., 2012; Andrews, Holmes, et al., 2008; van Wyk, Weir, Andrews, Fiedler, & Callaghan, 2009; Weir et al., 2007).

5.1.4 Lifts with Poor Coupling

Coupling was only perceived to be significantly riskier than its default counterpart when lifting from the floor to the floor. When lifting from the floor to the floor, the poorly coupled lift was perceived to be 30% riskier than the good coupled lifts, which translates to an average increase of approximately 1.30 Likert units. With that being said, the poor coupling video was also rated higher at the waist-to-waist height, though the difference was insignificant (difference of approximately 0.56 Likert units). Poor coupling did not seem to create a large effect on risk perception for medium weighted lifts.

5.1.5 Repetitive/Frequent Lifts

Despite being one of the three tenets of ergonomic assessment (Force, Posture, and Repetition), repetition of a lift or altered lifting frequencies were not perceived as any more risky than a single lifting instance except when lifting from the waist to the waist. Repetition of a lift and lift duration has been shown to increase the cumulative aspect of manual materials handling as well as the speed of a lift has been shown to increase peak low back loading; both are significant contributors to low back injury risk (Callaghan & McGill, 2001; Greenland, Merryweather, & Bloswick, 2013; R. Norman et al., 1998). One possible explanation as to why participants did not perceive this factor as risky was possibly because they were not able to recognize that the videos had a different lifting frequency than the default videos. This could be due to two reasons. First, the default videos had lifts lasting 3-4 seconds, which would translate to a lifting speed of approximately 15 lifts/minute, while the altered frequency videos had the subject lifting at 8 lifts/minute; therefore, since the default lifts were so quick and there was no information given as to the duration of each lift, survey participants may not have been able to discern lifting speed. Second, since the settings of the altered frequency lifts were similar to those of their default counterparts, survey participants may not have understood that the multiple lift videos represented an example of a job that required constant, repeated lifts during the day. Had similar length videos been filmed in a different setting that showed a purely MMH job, like a manufacturing/assembly line, risk perceptions may have differed. This, however, was not done because the goal of the study was to cater the message to small businesses where MMH is a part of the daily work, but not the only work done.

5.1.6 Lifts Requiring Reach

Lifts requiring horizontal reach were perceived to be riskier than near lifts when lifting from floor to waist and when lifting from the waist to the waist. Despite not being significantly different, the far lifting video going from floor to the floor, on average, also had a higher Likert score than its counterpart video. Again, the horizontal distance used (60 cm or 2 feet) was chosen so participants could see the extreme postures in the short duration videos and in doing so, participants were able to recognize the majority of reaching tasks that require 60 cm of reach.

5.1.4 Lifting Technique

Stooping was rated as riskier than squat lifting. Particularly in the videos that were shown to survey participants, the video subject was asked to perform stoop lifts, which were defined as lifts where the knees bend very little (knee angle of greater than 135°) (Straker, 2003). Due to the participant's flexibility, they did not bend their legs at all and instead bent their spine which allowed for some of the highest ratings of risk amongst all of the tasks (FW Stoop average = 7.73 ± 2.30).

As stated before, the evidence is unclear as to whether there truly is a "best" technique for lifting. Physiologically, studies show that squat lifting is more taxing on the cardiovascular system and this seems to be more a function of lifting and lowering the body than it is a function of the mass being lifted (Hagen, Harms-Ringdahl, & Hallen, 1994; Straker, 2003). In contract, based on a novel kinematics-based quasi-static lifting model that accounted for nonlinear passive ligament forces, muscle wrapping, and muscle forces, Bazrgari et al. endorsed the use of the squat lifting technique because it reduced net moments, muscle forces, and internal spinal loading (Bazrgari, Shirazi-Adl, & Arjmand, 2006). A review of the biomechanical literature found that there is not enough evidence to support squat lifting as a way to decrease low back injury risk (van Dieën, Hoozemans, & Toussaint, 1999). This review found that intra-discal pressure and spinal shrinkage caused by lifting was similar in both techniques, and that although spinal shear and moments may be lower in squatting, models estimate that moments and compression are higher in squatting (van Dieën et al., 1999).

There seems to be a discord with how people perceive lifting techniques and what the literature says about lifting techniques. This may be another case where the evidence in the literature has not been translated successfully to the general population. However, it should be noted that lift training in any one specific technique may not be successful. Another literature review that was done in 2003 advocated for educating workers in general lifting guidelines so they may create their own individualized techniques; lifting techniques that optimize trunk and knee flexion angles to reduce muscular effort in addition to inhibiting low back injury risk (Burgess-Limerick, 2003).

5.1.5 Weight of Object

There was a clear trend where people perceived heavier lifts as being riskier than medium or light lifts. This was evident at all lifting heights except the CW height combination where the heavy and medium weight tasks were seen as equally risky. As previously discussed, the medium CW lift could have been perceived as including a horizontal reach and so it may have been somewhat of an outlier and so for the purposes of this part of the discussion, it is possible that this weight-risk perception trend could exist at all heights.

This perception of risk increasing as the weight of the load increases agrees with what has been found in the literature. Increasing load has been shown to increase the biomechanical risk of lifting. This increased risk stems from increased muscle activity, low back moments and compression (Hoozemans et al., 2008; Marras et al., 2006; McGill, 1997). Although the weight of the load is one of the most important factors of any MMH task, it has been found that up until a certain load weight, it is the position of the load relative to the body that better modulates low back injury risk rather than the object weight due to the majority of the spinal loading coming from the person's own trunk and upper limb segment weights (Hoozemans et al., 2008). A specific example is from a study by Hoozemans et al. that looked at the effect of lifting height and load mass on low back loading which found that going from 7.5 to 15 kg significantly affected low back moment and compression, but produced similar shear values while manipulating the handle height of the object (four different heights starting at 0.32 m and going to 1.55 m) had stronger and significant effects for all three low back loads (Hoozemans et al., 2008).

5.1.6 Use of a Back Belt

It was perceived to be less risky to lift with a back belt (BB) than it was to lift without one (VH). From the results of this study, the VH (default, medium weighted, floor to waist) videos were rated significantly higher (an increase of 23% in Likert score) than the BB video ($p<0.001$). However, after reading the back belt message, participants' risk perception of back belts increased, leading to a difference of only 7% between back belt and non-back belt lifting Likert scores.

Since their introduction into the work force, it has been stated that back belts help prevent injury through multiple mechanisms. Back belts are a form of personal protective equipment (PPE) that claims to redistribute forces of the spine by increasing intra-abdominal pressure, decreases muscle fatigue by increasing muscle support, decreases spinal range of motion, encourages safer lifting techniques through increased proprioceptive input, and creates a soothing effect from local tissue warming (Barron & Feuerstein, 1994). A review examining these five different mechanisms as well as epidemiological studies on the effectiveness of back belts concluded that, overall, studies showed conflicting evidence which supported and refuted the benefits of back belts listed above (Minor, 1996). A more recent example of conflicting findings refers to the ability of back belts being able to make people feel they could lift more weight. Two studies done in 1996 and 2003 showed that psychophysically, workers who used belts felt they could lift greater loads, and actually did lift greater loads when performing lifting tasks with self-selected weights (Chen, 2003; Magnusson et al., 1996). In contrast, a study done in 2008 also asked participants to choose weights they perceived they could work with for long periods of time without undue muscular and cardiovascular stress and found that worker perceptions were not affected by back belt use (Ciriello, 2008). In a more longitudinal study where participants suffering from sub-acute low back pain were followed for 90 days, Calmels et al. showed evidence that temporary use of a back belt helped decrease medication consumption and increased functionality at work (Calmels et al., 2009). And so, although it is possible that back belts may help some, it seems to not really affect others. At its worst, some back belt mechanisms have been thought to possibly increase risk of injury or increase injury severity (Marley & Duggasani, 1996; McGill et al., 1990; Minor, 1996). With that being said, and in accordance with the back belt message used in the study and the recommendations of McGill et al., the effect of back belts on injury prevention are unclear and thus, it is believed that they should be used temporarily and if workers require back belts to accomplish a work task, more energy should be spent focusing on the redesign of the task rather than simply introducing a piece of PPE and expecting no new injuries to occur (Ciriello, 2008; McGill, 1993).

Overall, participants could recognize some lifting risk factors. Using this knowledge of how people perceive risk factors of lifting, future studies can be geared towards new campaign messages to help steer people towards what truly is risky.

5.2 Message Efficacy

Overall, the lifting height message increased the participants' perceptions of risk in some of the lifts when watching the same videos a second time. Specifically, when people were warned about the risks of low-lying lifts, their perceptions of tasks that started from the floor or calf seemed to have the greatest increases, up to 60% (p<0.05). Unexpectedly, there was a video that had negative changes, meaning that participants thought of the knee-to-waist (KW) heavy lift as less risky than before. There were other videos that also decreased in score; however, their changes did not show significance due to the Bonferroni correction. This could mean that the lifting height message improved participant's ability to discriminate a safer lifting height from a riskier lifting height. Further, this ability to discriminate a safer lifting height from a riskier lifting height seems to have a threshold at the knee height. From the correlations, it was found that participant ratings in this group agreed more with 3DMatch post educational message as well.

The back belt message also increased participants' perceptions of risk by up to 28% (p<0.05). Only 1 of the 44 videos had a participant lifting a load from FW while using a back belt. In the back belt message group, a large increase in perceived risk was seen in the back belt lifting video; however, when considering the other videos that also showed increases, a systematic increase could be seen in the FW and WW videos, which could possibly due to familiarization. Although the paired T-tests revealed significant changes between these pre-post scores, the magnitudes of these changes are much smaller than the increases seen in the lifting height message group (Back Belt Message change range: 0.730 to 0.876 Likert Units versus

Lifting Height Message change range: 1.555 to 2.329 Likert Units) and therefore are not as important from a risk assessment viewpoint.

5.3 Demographic Factors

Overall, all Pearson Product Moment Correlations between ‘x’ (3DMatch scores) and ‘y’ (Likert scores) were positive and significant, meaning that as 3DMatch risk scores increased, so too did the risk ratings of all of the groups. The majority of groups showed R-values between 0.45 and 0.55, meaning that groups had a weak to moderate correlation with 3DMatch.

Within each demographic category, there were no strong and clear linear trends (Table 4.15). Risk ratings of male participants correlated slightly better than females with 3DMatch (R=0.526 and 0.472 respectively). This slight difference could simply be due to the participant population, or possibly, since gender and sex have been shown to affect lifting kinematics and spinal loading, that females perceived lifting risk factors differently than males and 3DMatch (Lindbeck & Kjellberg, 2001; Marras, Davis, & Jorgensen, 2003). For the low back pain demographic, it was hypothesized that since injured individuals have been shown to lift differently than asymptomatic individuals and have decreased perceptions of physical capacity, low back injured participants could be more sensitive to assessing risk, but this was not the case. Although participants who suffered a low back injury resulting in lost time seemed to correlate more with 3DMatch as time passed since their last injury (6 months group having R=0.397, 1 year group having R=0.445, and 5 year group having R=0.554, Table 4.15), those who reported never having a low back injury resulting in lost time correlated almost as well as the 5 year group at an R=0.500. It was expected that as work experience increased, so too would the ability to assess postures and, in consequence, lifting risk (Yeung, Genaidy, Deddens, & Leung, 2003). In fact, the opposite occurred, participants who had been working in their sector the least amount of time correlated best with 3DMatch. With that being said, the R-values were close to each other and were moderate in strength and ranged from 0.45 to 0.54. This could possibly be due to this group, being the newest work force members, were also the most recently trained individuals in their jobs. In terms of role in the company, workers, supervisors, and employers (N=4136, 660, 616 respectively) attained very similar R-values (0.526, 0.493, 0.508 respectively) while purely health and safety representatives (N=1232) correlated worst with 3DMatch in this group at an R=0.440. With that being said, all of the R-values of the 4 roles are similar in that they are all moderate in strength. This possibly means that risk perceptions, when compared with a standard risk assessment tool, are similar across roles and positions. Finally, it was expected that as familiarity with ergonomics increased, so would correlation with 3DMatch; however, this did not happen linearly. Except for the 0 familiarity with ergonomics group correlating least with 3DMatch (R-value = 0.389), familiarity groups 1 through 5 ranged, in no particular trend, from 0.465 to 0.588.

From the results of the 6 low back experts , several things could be possible. Firstly, the scale asked for self-reported scores of familiarity and thus, did not truly have any quantifiable meaning. In other words, instead of asking each participant about how much training or education they had received in ergonomics or low back pain, this scale simply asked for a self-reported value; however, this method was chosen to help decrease participant survey fatigue and help increase participant anonymity. From the expert group's results, there were those who possibly undervalued themselves by not choosing a score of 5. This could be due to the natural tendency of wanting to regress to the mean by not choosing the most extreme score. However, based on the associated R-values, even within the expert's 5 group's scores, there were large amounts of variation. This leads to the second possibility that risk perception is a very complicated process and it could be that participants did not only look at biomechanical factors. Based on the bottom-up and top-down processing model of perceiving events posited in psychology, when a participant sees another person doing a lift, they would first see the lift as it is (bottom-up), and then using their past experiences and knowledge, they would begin to layer on different meanings to associate with the lift they just saw (top-down). Since each video was so short and lacked quantifiable measures (other than object weight), for some participants, they possibly chose a risk rating simply based on intuition as they likely had no formal training. This intuitive value could have been partly based on how much effort they believed the task would require; perception of effort has been shown to relate well to NIOSH's lifting index (risk) (Kim, Martin, & Chaffin, 2004; Yeung et al., 2003). Effort could have been assessed through various visual cues such as: if there were changes to the lifter's facial expression, or whether their movements seemed rushed or unsmooth (Moore & Garg, 1995). The third reason, is that although 3DMatch is a reliable, valid, and widely used risk assessment tool, it may not capture all aspects of injury risk (Parkinson et al., 2011; Sutherland et al., 2008). Many people rated lifts much differently than 3DMatch, even so, all R-values scores were positive, meaning that everyone agreed that the lifting tasks were risky, only, they varied in what they found to be risky. One possible explanation for this disconnect could be due to 3DMatch treating the trunk as a single segment, when in reality, the subject in this video flexed their spine a great deal in order to perform the stoop lift, which may have caused rating participants to rate the risk of this video rather highly (Table 4.14).

Overall, it can be said that although there were differences in how participants perceived risk, as a participant population, there were no strong relationships between demographic groups and the chosen standard.

5.4 Implications for the Work Place

Using simple messages to transfer practical ergonomic knowledge is a feasible strategy to raise awareness of workplace lifting hazards. In other words, people are able to recognize the risk factors we are teaching them about. In order to induce ergonomic change, hazards must first be identified, risks must then be assessed and then these hazards must be controlled (R Wells et al., 2004). The first step in the change process requires that these hazards be recognized and the results show that this step can be affected. As previously stated, ergonomic training has been shown to lead to increases in worker self-efficacy where workers made small workplace changes to decrease discomfort, pain, and risk factor exposure (Greene et al., 2005; Harrington & Walker, 2004; Rizzo & Pelletier, 1997; Robson, 2010). Ultimately, the ones most affected by accidents and injuries are the everyday workers and operators; however, a study investigating the perceptions and attitudes towards risks at a transport work place have shown that although workers feel responsible for helping control accidents in the workplace, they openly welcome advice and continued support (through training and other KT means) from management and authorities to help decrease workplace injuries (Majekodunmi & Farrow, 2009). Knowledge transfer was successful due to knowledge being used conceptually. Participants demonstrated an increase in risk awareness and recognition. In other words, people can recognize a risk factor of lifting, and their awareness of it can be improved. With the above results, using simple educational messages may help mitigate risky lifts and if the hazards are then controlled, help to decrease low back injury incidences in the workplace.

5.5 Limitations

There were limitations to this study. The nature of the Likert scale simplifies risk perception; however, since assessing lifting risk in this study was meant to simulate how a worker would, on a day-to-day basis, look at and perceive a lift, an overall impression of each task's risk was required. Further, although each video participant was coached to perform so that only one variable was altered at a time, there is the possibility that some survey participants did not perceive the risk factors of each video as it was intended when the videos were filmed. Furthermore, although there are many different sectors of work, only 5-6 are represented in the videos; however, not all types of work could be represented and the settings were chosen to span general types of work from office to industrial. As well, since some participants filled out a paper, rather than an electronic survey, scores may have been affected by the survey process used; however, the process of administering the paper survey was essentially scripted, rehearsed, and kept as consistent as possible between collection sessions so as to not produce any additional and unexplainable effects. A basic difference between the two methods was that the paper version had some human interaction (the researcher would guide the participants through the survey) which could have increased attentiveness, which could have increased the learning effect (Robson, 2010). Also, the manipulated NIOSH risk factors were dichotomized into neutral and extreme postures; however, this was done to make it more recognizable for a lay audience. Additionally, although the awareness of risk factors could be affected, this does not necessarily mean that risky behaviour will decrease; however, future research will look into the longer term effects of such simple educational messages.

5.6 Future Investigations

Future investigations for risk perception need to look into more graded changes in risk factors to see how sensitive people are to reach, twist, or frequency. Additionally, future experiments need to look into possibly doing semi-structured interviews to investigate and find out what people look at when judging the riskiness of a lift. Future investigations for message efficacy should examine knowledge utilization and assess if these messages have an effect on mitigating risky behaviours in the work place by seeing if participants have used the knowledge instrumentally, strategically, or politically. All of this is with the ultimate goal to see if these simple messages can help decrease the incidence of low back pain in the work place from overexertion injuries.

6. Conclusions

The purpose of this study was to assess the efficacy of a simple educational message on risk factor recognition, investigate the risk perception of lifting factors, and compare the risk assessment capabilities of people to an industrially used risk assessment tool. The simple educational message had a significant effect on how participants perceived the risk factor of lifting height; it allowed participants to better discriminate a less risky lifting height from a more risky lifting height. The message is simple enough that its dissemination to small workplaces could be feasible. Additionally, manipulating manual materials handling factors also had a significant effect on risk perception; generally, the more a lift deviates from a waist height lift, the riskier it was perceived. Further, participants' risk ratings significantly and positively correlated with a risk assessment tool, albeit moderately at best. These results provide support for the use of simple educational messages to increase conceptual awareness risk factors during lifting; the first step in the prevention cycle of identifying hazards/assessing risks and controlling hazards.

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8. Appendix A: Participant Forms

8.1: Information Consent Form – Video Subjects

Information for Video Lifting Participants:

Assessing Worker's Ability to a Lifting Risk Factor for Low Back Pain: Investigating the Efficacy of a Simple Educational Message

February 2015

Title of Project:	**Assessing Worker's Ability to Recognize a Lifting Risk Factor for Low Back Pain: Investigating the Efficacy of a Simple Educational Message**
Faculty Supervisor:	Richard Wells University of Waterloo, Department of Kinesiology wells@uwaterloo.ca (519) 888-4567 Ext. 33069
Student Investigator:	Binh Ngo University of Waterloo, Department of Kinesiology bngo@uwaterloo.ca

Purpose of this Study

The overall objectives of this research study are to determine the ability of workers, supervisors and experts to identify activities that have the potential to result in low back pain. The purpose of this part of the study is to gather videos of people performing lifting tasks in a number of workplace settings. The study is for a Master's thesis.

Exclusion Criteria

The following criteria will be used to exclude persons from the lifting videos of the study:

1. An injury to your low back in the past 6 months or current low back pain

2. Inability to perform 30-40 common lifting tasks of light to moderate weight objects in 45 minutes

Time Commitment

The total time commitment (i.e., total duration of video collection session) will be approximately 45 minutes.

Procedures Involved in this Study

A video camera will be used to capture the lifting tasks you will perform.

You will be asked to perform 10 different lifting tasks 3-4 times each. Each task lasts 5-15 seconds. Tasks may vary in terms of load weight, load position, coupling type, lifting technique and lifting frequency.Lifting tasks will be reflective of every day work tasks. Additional care will be taken to ensure adequate rest is given between lifts and that lifts do not exceed the 75^{th} percentile maximal acceptable weight limits. These lifting videos will be used in a web survey. The lifting videos will not be shown publicly and will only be used for teaching and research purposes.

An example of a task would be lifting a medium weighted object, like a tool box or 3 reams of paper (3-10 kg/6-22 lbs), from floor height to a waist height shelf using a squat lift. Another example would be to lift a heavier object, like a box of 24 bottles of beer (>15 kg/>33 lbs), from knee height to a table using a squat lift.

It is important for you to know that your face will not be censored (covered up) in the final video. This is to ensure that lifting videos look more natural and are more representative of what people would see in every-day work places. If requested, filming will be carried out so as to minimize the amount of your face seen in each lift.

Risks to Participation and Associated Safeguards

You may experience fatigue while performing the lifts. However, rest time will be provided between each lift to help prevent muscular fatigue and soreness. If you have any questions or concerns about a particular lift, please inform the research associate before performing the lift.

Participation

Participation is voluntary and you may withdraw from participation in this study at any time without penalty. Additionally, participants using work time to participate in this study have been granted permission to do so from their supervisors and participation will not affect participant performance on the job or the status of their position. In order to withdraw participation, indicate this to the research associate by saying, “I no longer wish to participate in this study” and all videos captured in the session will be erased.

Benefits of Participation

The information obtained from this research aims to give insight into how people perceive risk factors for low back pain and whether or not awareness of these risk factors can be influenced using simple educational messages.

Confidentiality

To ensure the confidentiality of your data, each participant will be identified by an identification code known only to the researchers. In addition, your identity will not be revealed in any publications produced from this research. All materials will be kept in a locked area marked only with an identification code. Video recordings will be kept on a password-protected computer and will be retained indefinitely.

Concerns About Your Participation

I would like to assure you that this study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee. However, the final decision about participation is yours. If you have comments or concerns resulting from your participation in this study, you may contact Dr. Maureen Nummelin, Chief Ethics Officer, at 519-888-4567 ext. 36005 or maureen.nummelin@uwaterloo.ca.

Questions About the Study

Feel free to ask questions at any time during the course of this study and to give your comments to the researchers. If you have additional questions or want any other information regarding this study, please contact:

Binh Ngo, MSc Candidate
University of Waterloo
Department of Kinesiology
bngo@uwaterlooc.ca

Richard Wells, PhD
University of Waterloo
Department of Kinesiology
519-888-4567 Ext 33069
wells@uwaterloo.ca

8.2: Consent to Participate – Video Subjects

Consent of Participant

I have read the information presented in the information letter about a study being conducted by *Binh Ngo and Dr. Richard Wells* of the Department of Kinesiology at the University of Waterloo. I have had the opportunity to ask any questions related to this study, to receive satisfactory answers to my questions, and any additional details I wanted. I am aware that I may withdraw from the study without penalty at any time by advising the researchers of this decision.

This project has been reviewed by, and received ethics clearance through a University of Waterloo Research Ethics Committee. I was informed that if I have any comments or concerns resulting from my participation in this study, I may contact the Director of Office of Research Ethics, Dr. Maureen Nummelin at 519-888-4567 ext. 36005 or maureen.nummelin@uwaterloo.ca.

With full knowledge of all foregoing, I agree, of my own free will, to:

Perform the lifting tasks and have the tasks video recorded. YES / NO

Consent to the use of my videos for research and educational purposes. YES / NO

By signing this consent form, you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

____________________________________ ______

Print Name

Signature of Participant

________________________________ ____________________________________

Dated

Witnessed

8.3: Feedback Form – Video Subjects

Feedback for Video Participants:

University of Waterloo

Date: ____________________

Thank you for your participation in this study, "Assessing workers' ability to recognize a lifting risk factor for low back pain: Investigating the efficacy of a simple educational message" conducted by Binh Ngo under the supervision of Dr. Richard Wells. As a reminder, the purpose of this study is to evaluate how people perceive risk factors of lifting and the effectiveness of a simple educational message.

Once all the data has been collected and analyzed for this project, I plan on sharing this information with the research community through conferences, presentations, and journal articles. If you are interested in receiving more information regarding the results of this study, or if you have any questions or concerns, please contact Binh Ngo or Richard Wells at the phone number or email address listed at the bottom of the page. If you would like a summary of the results or a copy of your lifting video, please let me know by providing me with your email address.

This project has been reviewed by, and received ethics clearance through a University of Waterloo Research Ethics Committee. In the event you have any concerns or comments resulting from your participation, you may contact Dr. Maureen Nummelin, Chief Ethics Officer, at 519-888-4567 ext. 36005 or maureen.nummelin@uwaterloo.ca.

Thank you again for your participation.

Binh Ngo
University of Waterloo
Department of Kinesiology
bngo@uwaterloo.ca

Richard Wells
University of Waterloo
Department of Kinesiology
519-888-4567 Ext. 33069
wells@uwaterloo.ca

8.4: Information Consent Form – Survey Participants

Survey Information and Consent

You are invited to participate in a research study conducted by Binh Ngo under the supervision of Dr. Richard Wells, Department of Kinesiology, at the University of Waterloo, Canada. The objectives of the research study are to determine the ability of workers, supervisors and experts to identify activities that have the potential to result in low back pain. Additionally, this research study will investigate the effects of a simple educational message on this ability. The study is for a Master's thesis.

If you decide to volunteer, you will be asked to complete a 20 minute online survey that is completed anonymously. Survey questions focus on the rating of lifting tasks with a small educational blurb midway through the questions. Participation in this study is voluntary. You may decline to answer any questions that you do not wish to answer by leaving them blank and you can withdraw your participation at any time by not submitting your responses. There are no known or anticipated risks from participating in this study.

It is important for you to know that any information that you provide will be confidential. All of the data will be summarized and no individual could be identified from these summarized results. Furthermore, the web site is programmed to collect responses alone and will not collect any information that could potentially identify you (such as machine identifiers).

This survey uses FluidSurveys™.The servers on which FluidSurveys™ operate are located in Canada, so survey data will be primarily stored in Canada however survey data may also be processed in and transferred or disclosed to countries in which SurveyMonkey™ affiliates are located and in which service providers are located or have servers. If you prefer not to submit your data through FluidSurveys™, please contact one of the researchers so you can participate using an alternative method such as through an email or paper-based questionnaire. The alternate method may decrease anonymity but confidentiality will be maintained. SurveyMonkey™ is a United States of America company. Consequently, USA authorities under provisions of the PATRIOT Act may access this survey data.

The data, with no personal identifiers, collected from this study will be maintained on a password-protected computer database in a restricted access area of the university. As well, the data will be electronically archived after completion of the study, maintained for ten years and then erased.

In appreciation of the time you have given to this study, you will be given a link at the end of the survey where you can enter your email into a draw for prizes. The prizes are a Kobo Mini eReader (valued at $49.99) and two $25 gift cards for Canadian Tire. Your odds of winning the prizes are based on the number of individuals who participate in the study. We expect that approximately 120 individuals will take part in the study. Information collected to draw for the prizes will not be linked to the study data in any way, and this identifying information will be stored separately, and then destroyed after the prizes have been provided. The amount received is taxable. It is your responsibility to report this amount for income tax purposes.

Should you have any questions about the study, please contact either Binh Ngo at bngo@uwaterloo.ca or Dr. Richard Wells at wells@uwaterloo.ca. Further, if you would like to receive a copy of the results of this study, please contact either investigator.

I would like to assure you that this study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee.However, the final decision about participation is yours. If you have any comments or concerns resulting from your participation in this study, please feel free to contact Dr. Maureen Nummelin in the Office of Research Ethics at 1-519-888-4567, Ext. 36005 or maureen.nummelin@uwaterloo.ca.

Thank you for considering participation in this study.

Consent to Participant

With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

[insert check box or radio button] "I agree to participate."

[insert check box or radio button] "I do not wish to participate (please close your web browser now)."

8.5: Feedback Form – Survey Participants

Thank you for participating in our Risk Factor Recognition Survey!

To enter the draw for one of the three prizes, please click the following link:

[*Insert link to different survey which will be used to collect email addresses*]

This survey was used to assess how people perceive risk factors of lifting and to test the effectiveness of a simple educational message. There were 2 educational messages for this study.

Educational Message #1:

"The closer your hands are to the ground when you are lifting an object, the more likely you will hurt your back. Even when lifting light objects, you can hurt your back. There is no "best" way to lift things from the ground, so to stop that problem altogether, 'Store it off the floor!'"

Educational Message #2:

"Back belts are sometimes used in work places to prevent low back pain. However, research shows back belts can increase the seriousness of an injury. Although people feel they can lift more weight when using them, they may lift too much weight and hurt themselves. Belts should only be used temporarily."

If you would like a copy of the results, please click the following link:

[*Insert link to different survey which will be used to collect email addresses*]

The study results will be sent to you by email to the address you provide by October, 2015.

If you have any general comments or questions related to this study, please contact Binh Ngo, Department of Kinesiology, bngo@uwaterloo.ca or Dr. Richard Wells, Department of Kinesiology, wells@uwaterloo.ca.

We would like to assure you that this study has been reviewed by, and received ethics clearance througha University of Waterloo Research Ethics Committee. If you have any concerns regarding your participation in this study, please contact Dr. Maureen Nummelin, the Director, Office of Research Ethics, at 1-519-888-4567, Ext. 36005 or maureen.nummelin@uwaterloo.ca.

8.6: Risk Factor Recognition Survey

Demographic Information

What is your

Age (yrs):__________________

Height:____________________ cm/m/feet/inches:_______________

Weight:____________________ kgs or lbs:_____________________

What is your sex? *Please select one*

- ○ Male
- ○ Female

What is your position in your company? *Please check all that apply*

- ☐ Worker
- ☐ Supervisor
- ☐ Employer
- ☐ Health and Safety Representative

What is your familiarity with ergonomics? *Please circle a number*

0	*1*	*2*	*3*	*4*	*5*
Not familiar at all					*Very familiar*

What sector do you currently work in? *Please check an option below*

○ Agriculture	○ Professional, scientific and technical services
○ Forestry, fishing, mining, quarrying, oil and gas	○ Business, building and other support services
○ Utilities	○ Educational services
○ Construction	○ Health care and social assistance
○ Manufacturing	○ Information, culture and recreation
○ Trade	○ Accommodation and food services

○ Transportation and warehousing	○ Other services
○ Finance, insurance, real estate and leasing	○ Public administration

How much work experience do you have in your current sector? *Please select one*

- ○ 1 year or fewer
- ○ More than 1 year but fewer than 5 years
- ○ More than 5 years but fewer than 10 years
- ○ 10 years or more

When did you last suffer a low back injury that resulted in lost work time?
Please select one

- ○ Within the last 6 months
- ○ Within the last year
- ○ Within the last 5 years
- ○ Never

How many employees work at your company? *Please select one*

- ○ 20 employees or fewer
- ○ More than 20 employees but fewer than 50 employees
- ○ 50 employees or more

Survey Rating Questions

Question A: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question B: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question C: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question D: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question E: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question F: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question G: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question H: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question I: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question J: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question K: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question L: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question M: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question N: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question O: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question P: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question Q: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question R: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question S: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question T: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question U: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question V: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question W: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question X: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question Y: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question Z: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question AA: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question AB: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question AC: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question AD: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question AE: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question AF: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question AG: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question AH: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question AI: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question AJ: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question AK: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question AL: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question AM: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question AN: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question AO: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question AP: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question AQ: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question AR: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question AS: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question AT: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question AU: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question AV: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question AW: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question AX: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question AY: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question AZ: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question BA: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question BB: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question BC: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question BD: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question BE: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question BF: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question BG: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question BH: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question BI: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question BJ: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question BK: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question BL: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question BM: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question BN: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question BO: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question BP: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question BQ: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question BR: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question BS: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question BT: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question BU: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question BV: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question BW: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question BX: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question BY: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0 1 2 3 4 5 6 7 8 9 10
Not likely *Extremely Likely*

Question BZ: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question CA: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question CB: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question CC: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question CD: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question CE: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question CF: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question CG: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question CH: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question CI: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

Question CJ: Choose a number that represents how likely you think doing this task several times a day, could eventually lead to low back pain.

0	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*
Not likely										*Extremely Likely*

9. Appendix B: Results

Table 9.1 One way ANOVA for Vertical Height: Descriptive Statistics

Name of Task	N	Mean	STDEV
CW	178	6.062	2.377
FW	534	4.809	2.253
KW	534	4.569	2.489
FF	534	4.277	2.355
FS	178	4.107	2.288
TW	178	2.910	2.048
WS	178	2.753	1.990
WW	534	2.105	1.870

Table 9.2 Reported *p*-values calculated from the Tukey-Scheffe post-hoc test for the multiple pare-wise comparisons of Vertical Height.

Least Squares Means for effect HCWords Pr > |t| for H0: LSMean(i)=LSMean(j) Dependent Variable: PreScore								
i/j	**CW**	**FF**	**FS**	**FW**	**KW**	**TW**	**WS**	**WW**
CW		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
FF	<.0001		0.9977	0.0350	0.7137	<.0001	<.0001	<.0001
FS	<.0001	0.9977		0.0685	0.5737	0.0006	<.0001	<.0001
FW	<.0001	0.0350	0.0685		0.8785	<.0001	<.0001	<.0001
KW	<.0001	0.7137	0.5737	0.8785		<.0001	<.0001	<.0001
TW	<.0001	<.0001	0.0006	<.0001	<.0001		0.9996	0.0157
WS	<.0001	<.0001	<.0001	<.0001	<.0001	0.9996		0.1302
WW	<.0001	<.0001	<.0001	<.0001	<.0001	0.0157	0.1302	

Table 9.3 Two Way ANOVA for VH vs. LOW: Descriptive Statistics

Name of Task	N	Mean	STDEV
LOW CW	178	3.989	1.957
LOW FW	178	4.921	2.537
LOW KW	178	3.213	1.943
VH CW	178	6.062	2.377
VH FW	534	4.809	2.253
VH KW	534	4.569	2.489

Table 9.4 Reported p-values calculated from the Tukey-Scheffe post-hoc test for the multiple pare-wise comparisons of VH vs. LOW.

Least Squares Means for effect Lcondn*HCWords Pr > |t| for H0: LSMean(i)=LSMean(j) Dependent Variable: PreScore						
i/j	**LOW CW**	**LOW FW**	**LOW KW**	**VH CW**	**VH FW**	**VH KW**
LOW CW		0.0132	0.0759	<.0001	0.0051	0.1358
LOW FW	0.0132		<.0001	0.0006	0.9973	0.6858
LOW KW	0.0759	<.0001		<.0001	<.0001	<.0001
VH CW	<.0001	0.0006	<.0001		<.0001	<.0001
VH FW	0.0051	0.9973	<.0001	<.0001		0.7205
VH KW	0.1358	0.6858	<.0001	<.0001	0.7205	

Table 9.5 Two Way ANOVA for Height Combination vs. Asymmetry: Descriptive Statistics

Name of Task	N	Mean	STDEV
ASY FF	178	6.101	2.457
ASY FW	178	6.191	2.328
ASY WW	178	2.994	2.076
VH FF	534	4.277	2.355
VH FW	534	4.809	2.253
VH WW	534	2.105	1.870

Table 9.6 Reported p-values calculated from the Tukey-Scheffe post-hoc test for the multiple pare-wise comparisons of Height Combination vs. Asymmetry.

Least Squares Means for effect Lcondn*HCWords Pr > |t| for H0: LSMean(i)=LSMean(j) Dependent Variable: PreScore						
i/j	**ASY FF**	**ASY FW**	**ASY WW**	**VH FF**	**VH FW**	**VH WW**
ASY FF		0.9996	<.0001	<.0001	<.0001	<.0001
ASY FW	0.9996		<.0001	<.0001	<.0001	<.0001
ASY WW	<.0001	<.0001		<.0001	<.0001	0.0006
VH FF	<.0001	<.0001	<.0001		0.0083	<.0001
VH FW	<.0001	<.0001	<.0001	0.0083		<.0001
VH WW	<.0001	<.0001	0.0006	<.0001	<.0001	

Table 9.7 Two Way ANOVA for Height Combination vs. Poor (CUP)/Good(VH) Coupling: Descriptive Statistics

Name of Task	N	Mean	STDEV
CUP FF	178	5.573	2.381
CUP FW	178	4.798	2.335
CUP WW	178	2.663	1.957
VH FF	534	4.277	2.355
VH FW	534	4.809	2.253
VH WW	534	2.105	1.870

Table 9.8 Reported p-values calculated from the Tukey-Scheffe post-hoc test for the multiple pare-wise comparisons of Height Combination vs. Poor (CUP)/Good(VH) Coupling.

Least Squares Means for effect Lcondn*HCWords Pr > |t| for H0: LSMean(i)=LSMean(j) Dependent Variable: PreScore						
i/j	**CUP FF**	**CUP FW**	**CUP WW**	**VH FF**	**VH FW**	**VH WW**
CUP FF		0.0479	<.0001	<.0001	0.0061	<.0001
CUP FW	0.0479		<.0001	0.1816	1.0000	<.0001
CUP WW	<.0001	<.0001		<.0001	<.0001	0.1218
VH FF	<.0001	0.1816	<.0001		0.0075	<.0001
VH FW	0.0061	1.0000	<.0001	0.0075		<.0001
VH WW	<.0001	<.0001	0.1218	<.0001	<.0001	

Table 9.9 Two Way ANOVA for Height Combination vs. Repeated (FREQ)/Single (VH) lifts: Descriptive Statistics

Name of Task	N	Mean	STDEV
FREQ FF	178	4.034	2.384
FREQ FW	178	4.326	2.446
FREQ WW	178	2.916	2.085
VH FF	534	4.277	2.355
VH FW	534	4.809	2.253
VH WW	534	2.105	1.870

Table 9.10 Reported p-values calculated from the Tukey-Scheffe post-hoc test for the multiple pare-wise comparisons of Height Combination vs. Repeated (FREQ)/Single (VH) lifts.

Least Squares Means for effect Lcondn*HCWords Pr > |t| for H0: LSMean(i)=LSMean(j) Dependent Variable: PreScore						
i/j	**FREQ FF**	**FREQ FW**	**FREQ WW**	**VH FF**	**VH FW**	**VH WW**
FREQ FF		0.9058	0.0004	0.8979	0.0057	<.0001
FREQ FW	0.9058		<.0001	0.9999	0.2690	<.0001
FREQ WW	0.0004	<.0001		<.0001	<.0001	0.0030
VH FF	0.8979	0.9999	<.0001		0.0085	<.0001
VH FW	0.0057	0.2690	<.0001	0.0085		<.0001
VH WW	<.0001	<.0001	0.0030	<.0001	<.0001	

Table 9.11 Two Way ANOVA for Height Combination vs. Far (HORI)/Near (VH) lifts: Descriptive Statistics

Name of Task	N	Mean	STDEV
HORI FF	178	4.646	2.378
HORI FW	178	6.247	2.125
HORI WW	178	2.775	2.027
VH FF	534	4.277	2.355
VH FW	534	4.809	2.253
VH WW	534	2.105	1.870

Table 9.12 Reported p-values calculated from the Tukey-Scheffe post-hoc test for the multiple pare-wise comparisons of Height Combination vs. Far (HORI)/Near (VH) lifts.

Least Squares Means for effect Lcondn*HCWords Pr > |t| for H0: LSMean(i)=LSMean(j) Dependent Variable: PreScore						
i/j	**HORI FF**	**HORI FW**	**HORI WW**	**VH FF**	**VH FW**	**VH WW**
HORI FF		<.0001	<.0001	0.5712	0.9800	<.0001
HORI FW	<.0001		<.0001	<.0001	<.0001	<.0001
HORI WW	<.0001	<.0001		<.0001	<.0001	0.0265
VH FF	0.5712	<.0001	<.0001		0.0070	<.0001
VH FW	0.9800	<.0001	<.0001	0.0070		<.0001
VH WW	<.0001	<.0001	0.0265	<.0001	<.0001	

Table 9.13 Two Way ANOVA for VH vs. TECH: Descriptive Statistics

Name of Task	N	Mean	STDEV
STP FW	178	7.730	2.298
STP KW	178	6.938	2.461
VH FW	534	4.809	2.253
VH KW	534	4.569	2.489

Table 9.14 Reported p-values calculated from the Tukey-Scheffe post-hoc test for the multiple pare-wise comparisons of VH vs. TECH.

Least Squares Means for effect Lcondn*HCWords Pr > |t| for H0: LSMean(i)=LSMean(j) Dependent Variable: PreScore				
i/j	**STP FW**	**STP KW**	**VH FW**	**VH KW**
STP FW		0.0198	<.0001	<.0001
STP KW	0.0198		<.0001	<.0001
VH FW	<.0001	<.0001		0.4375
VH KW	<.0001	<.0001	0.4375	

Table 9.15 Two Way ANOVA for VH vs. WEIGHTS: Descriptive Statistics

Name of Task	N	Mean	STDEV
HEV CW	178	6.084	2.343
HEV FF	178	7.382	2.139
HEV FW	178	7.107	2.143
HEV KW	178	5.961	2.166
HEV WW	178	4.376	2.157
VH CW	178	6.062	2.377
VH FF	534	4.277	2.355
VH FW	534	4.809	2.253
VH KW	534	4.569	2.489
VH WW	534	2.105	1.870
LIT CW	178	2.264	2.018
LIT FF	178	3.197	2.756
LIT FW	178	2.371	2.178
LIT KW	178	1.904	1.797
LIT WW	178	0.421	0.931

Table 9.16 Reported p-values calculated from the Tukey-Scheffe post-hoc test for the multiple pare-wise comparisons of VH vs. WEIGHTS.

Least Squares Means for effect Lcondn*HCWords Pr > |t| for H0: LSMean(i)=LSMean(j) Dependent Variable: PreScore															
i/j	**HEV CW**	**HEV FF**	**HEV FW**	**HEV KW**	**HEV WW**	**VH CW**	**VH FF**	**VH FW**	**VH KW**	**VH WW**	**LIT CW**	**LIT FF**	**LIT FW**	**LIT KW**	**LIT WW**
HEV CW		0.0056	0.1559	1.0000	<.0001	1.0000	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
HEV FF	0.0056		1.0000	0.0007	<.0001	0.0040	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
HEV FW	0.1559	1.0000		0.0438	<.0001	0.1271	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
HEV KW	1.0000	0.0007	0.0438		<.0001	1.0000	<.0001	0.0009	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
HEV WW	<.0001	<.0001	<.0001	<.0001		<.0001	1.0000	0.9832	1.0000	<.0001	<.0001	0.0291	<.0001	<.0001	<.0001
VH CW	1.0000	0.0040	0.1271	1.0000	<.0001		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
VH FF	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001		0.3367	0.9893	<.0001	<.0001	0.0038	<.0001	<.0001	<.0001
VH FW	<.0001	<.0001	<.0001	0.0009	0.9832	<.0001	0.3367		0.9987	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
VH KW	<.0001	<.0001	<.0001	<.0001	1.0000	<.0001	0.9893	0.9987		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001
VH WW	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001		1.0000	0.0030	0.9999	1.0000	<.0001
LIT CW	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000		0.3125	1.0000	0.9998	<.0001
LIT FF	<.0001	<.0001	<.0001	<.0001	0.0291	<.0001	0.0038	<.0001	<.0001	0.0030	0.3125		0.5611	0.0061	<.0001
LIT FW	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.9999	1.0000	0.5611		0.9954	<.0001
LIT KW	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	1.0000	0.9998	0.0061	0.9954		0.0002
LIT WW	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	<.0001	0.0002	

Table 9.17: Average Post-Pre percent differences. N is the number of trials and SD is the standard deviation of each score. ↑'s denote a significant increase in risk perception while ↓'s denote a significant decrease in risk perception (adjusted $p<0.05$). C=Calf, W=Waist, F=Floor, S=Shoulder, K=Knee, T=Thigh. So CW=a lift from calf to waist height. N=267 denotes tasks with multiple videos.

		Back Belt Message					Lifting Height Message				
HCWords	Lcondn	N	Mean	STDEV	p-value	% Change from Pre	N	Mean	STDEV	p-value	% Change from Pre
CW	VH	89	0.0449	1.827	0.817	1%	89	0.528	1.720	0.0047	8%
	HEV	89	0.0899	1.670	0.6128	2%	89	0.955	2.205	<.0001	15% ↑
	LIT	89	0.0225	1.617	0.896	1%	89	0.472	2.122	0.0388	19%
	LOW	89	0.449	1.430	0.0039	13%	89	1.034	1.715	<.0001	24% ↑
FF	ASY	89	0.472	1.859	0.0188	8%	89	0.573	1.764	0.0029	9%
	CUP	89	-0.0674	1.845	0.7311	-1%	89	0.809	1.870	<.0001	13% ↑
	FREQ	89	0.337	1.692	0.0635	9%	89	1.135	1.990	<.0001	26% ↑
	HEV	89	-0.180	1.910	0.3771	-3%	89	0.697	1.555	<.0001	9% ↑
	HORI	89	-0.0899	1.782	0.6352	-2%	89	1.214	1.806	<.0001	24% ↑
	LIT	89	-0.360	2.351	0.1527	-15%	89	0.281	2.954	0.3721	7%
	VH	267	0.187	1.724	0.0771	5%	267	1.236	2.059	<.0001	27% ↑
FS	VH	89	0.449	1.846	0.024	12%	89	1.506	1.829	<.0001	33% ↑
FW	ASY	89	0.180	2.119	0.4256	3%	89	0.798	1.646	<.0001	19% ↑
	BB	89	0.730	1.536	<.0001	20% ↑	89	2.146	2.135	<.0001	33% ↑
	CUP	89	0.337	1.492	0.0358	8%	89	1.607	1.723	<.0001	31% ↑
	FREQ	89	0.360	1.766	0.058	9%	89	2.079	2.283	<.0001	45% ↑
	HEV	89	-0.124	1.744	0.5055	-2%	89	0.876	1.698	<.0001	12% ↑
	HORI	89	-0.214	1.843	0.2775	-4%	89	0.775	1.643	<.0001	12% ↑
	LIT	89	-0.0225	1.270	0.8678	-1%	89	1.607	2.329	<.0001	60% ↑

	LOW	89	0.876	2.088	0.0002	20% ↑	89	0.708	2.144	0.0025	13%
	STP	89	0.169	1.811	0.3822	2%	89	0.719	1.624	<.0001	9% ↑
	VH	267	0.0974	1.608	0.3232	2%	267	1.442	1.947	<.0001	28% ↑
	HEV	89	-0.112	1.661	0.5251	-2%	89	-0.685	1.628	0.0001	-11% ↓
	LIT	89	-0.326	1.02	0.0034	-19%	89	0.101	1.816	0.6006	5%
KW	LOW	89	-0.258	1.284	0.0609	-9%	89	0.517	1.890	0.0115	15%
	STP	89	0.405	1.388	0.0072	6%	89	-0.202	1.908	0.3201	-3%
	VH	267	0.0974	1.881	0.3984	2%	267	0.506	2.027	<.0001	10% ↑
TW	VH	89	0.0337	1.418	0.8231	1%	89	-0.438	1.712	0.0178	-14%
WS	VH	89	0.157	1.492	0.3225	6%	89	-0.169	1.509	0.295	-6%
	ASY	89	0.214	1.682	0.2344	8%	89	-0.124	1.845	0.5291	-4%
	CUP	89	0.708	1.502	<.0001	28% ↑	89	0.124	1.858	0.5318	4%
	FREQ	89	0.315	1.729	0.0896	12%	89	-0.0899	1.893	0.6552	-3%
WW	HEV	89	0.191	2.039	0.3792	4%	89	-0.494	2.095	0.0286	-11%
	HORI	89	-0.135	1.367	0.3546	-5%	89	-0.596	1.857	0.0033	-20%
	LIT	89	0.0449	0.796	0.5958	11%	89	0.0899	1.512	0.5764	20%
	VH	267	0.101	1.226	0.1791	5%	267	-0.124	1.498	0.1788	-5%

Table 9.18 3DMatch raw and normalized outputs for all 44 lifting videos.

Name of Task	Frame	Joint Compression (N)	Joint A/P Shear (N)	Normalized Compression	Normalized Shear
Heavy, FW lift	Lift-Off	6544	-106.603	1.925**	-0.213
	Mid 1	5767	-156.424	1.696	-0.313
	Mid 2	1727	132.847	0.508	0.266
	End	2365	196.295	0.696	0.393
Heavy, CW lift	Lift-Off	2017	163.851	0.593	0.328
	Mid 1	4756	-269.251	1.399**	-0.539
	Mid 2	3651	-343.213	1.074	-0.686
	End	1597	117.210	0.470	0.234
Heavy, FF lift	Lift-Off	6817	-102.408	2.005**	-0.205
	Mid 1	6817	-102.408	2.005**	-0.205
	Mid 2	4434	-255.708	1.304	-0.511
	Mid 3	2061	9.943	0.606	0.020
	Mid 4	6817	-102.408	2.005**	-0.205
	End	5695	-268.011	1.675	-0.536
Heavy, KW lift	Lift-Off	3848	-31.829	1.132**	-0.064
	Mid	1382	86.710	0.406	0.173
	End	1727	132.847	0.508	0.266
Heavy, WW lift	Lift-Off	1518	106.705	0.446**	0.213
	End	1518	106.705	0.446**	0.213
Light, CW lift	Lift-Off	2444	-188.937	0.719**	-0.378
	Mid	1613	-107.164	0.475	-0.214
	End	1135	34.456	0.334	0.069
Light, FF lift	Lift-Off	2690	-167.949	0.791**	-0.336
	Mid	2690	-167.949	0.791**	-0.336
	End	2690	-167.949	0.791**	-0.336
Light, FW lift	Lift-Off	2936	-214.776	0.864**	-0.430
	Mid	1747	-93.704	0.514	-0.187
	End	1117	28.029	0.328	0.056
Light, KW lift	Lift-Off	1959	-72.009	0.576**	-0.144
	Mid	1086	14.145	0.3193	0.028
	End	1158	41.130	0.340	0.082
Light, WW lift	Lift-Off	1077	8.547	0.317	0.017

	Mid	1084	13.094	0.319	0.026
	End	1117	28.177	0.329**	0.056
Med, CW lift	Lift-Off	3956	-146.085	1.163**	-0.292
	End	2343	-72.663	0.689	-0.145
Med, Asymmetric, FF lift	Lift-Off	3691	-230.516	1.086	-0.461
	End	4336	-216.614	1.275**	-0.433
Med, FF Lift	Lift-Off	4186	-132.768	1.231**	-0.266
	End	3998	-145.403	1.176	-0.291
Med, Coupling, FF Lift	Lift-Off	3779	-232.260	1.112**	-0.465
	Mid	2131	-93.370	0.627	-0.187
	End	3779	-232.260	1.112**	-0.465
Med, Frequency, FF lift	Lift-Off 1	2487	-43.781	0.732**	-0.088
	End 1	2487	-43.781	0.732**	-0.088
	Lift-Off 2	2487	-43.781	0.732**	-0.088
	End 2	2487	-43.781	0.732**	-0.088
	Lift-Off 3	2487	-43.781	0.732**	-0.088
	End 3	2487	-43.781	0.732**	-0.088
	Lift-Off 4	2487	-43.781	0.732**	-0.088
	End 4	2487	-43.781	0.732**	-0.088
Med, Horizontal Reach, FF lift	Lift-Off	4015	-113.687	1.181**	-0.227
	End	3423	-154.841	1.007	-0.310
Med, FF lift	Lift-Off	3269	-157.463	0.962**	-0.315
	Mid 1	3269	-157.463	0.962**	-0.315
	Mid 2	2720	-199.486	0.800	-0.399
	End	3269	-157.463	0.962**	-0.315
Med, FF lift	Lift-Off	2433	-46.469	0.716	-0.093
	End	3361	-155.890	0.989**	-0.312
Med, FS lift	Lift-Off	3423	-154.841	1.007**	-0.310
	Mid	1777	-112.014	0.523	-0.224
	End	1380	86.483	0.406	0.173
Med, FW lift	Lift-Off	3729	-149.755	1.097**	-0.300
	Mid	2088	-89.288	0.614	-0.179
	End	1446	96.507	0.425	0.193

Med, Asymmetric, FW lift	Lift-Off	3691	-230.516	1.086**	-0.461
	Mid	2188	-86.294	0.644	-0.173
	End	1195	50.911	0.351	0.102
Med, Back Belt, FW lift	Lift-Off	3283	-164.634	0.966**	-0.329
	Mid	2065	-81.828	0.607	-0.164
	End	1105	23.494	0.325	0.047
Med, Coupling, FW lift	Lift-Off	3722	-236.211	1.095**	-0.472
	Mid	2935	-214.871	0.863	-0.430
	End	1500	104.264	0.441	0.209
Med, Frequency, FW lift	Lift-Off 1	2644	-210.780	0.778**	-0.422
	Mid 1	1754	-112.660	0.516	-0.225
	End 1	1224	57.671	0.360	0.115
	Lift-Off 2	2644	-210.780	0.778**	-0.422
	Mid 2	1754	-112.660	0.516	-0.225
	End 2	1224	57.671	0.360	0.115
	Lift-Off 3	2644	-210.780	0.778**	-0.422
	Mid 3	1754	-112.660	0.516	-0.225
	End 3	1224	57.671	0.360	0.115
	Lift-Off 4	2644	-210.780	0.778**	-0.422
	Mid 4	1754	-112.660	0.516	-0.225
	End 4	1224	57.671	0.360	0.115
Med, Horizontal Reach, FW lift	Lift-Off	3695	-157.713	1.087**	-0.315
	Mid 1	3337	-183.156	0.981	-0.366
	Mid 2	1191	49.861	0.350	0.100
	End	1487	102.460	0.437	0.205
Med, FW lift	Lift-Off	3205	-220.575	0.943**	-0.441
	Mid	2590	-203.677	0.762	-0.407
	End	1182	47.643	0.348	0.095
Med, Stoop, FW lift	Lift-Off	2647	-261.456	0.778	-0.523
	Mid	3696	-171.688	1.087**	-0.343
	End	1598	117.341	0.470	0.235
Med, FW lift	Lift-Off	3954	-146.111	1.163**	-0.292
	Mid	3954	-146.111	1.163**	-0.292
	End	1535	109.044	0.451	0.218
Med, KW lift	Lift-Off	2487	-43.781	0.732**	-0.088
	Mid	1895	-99.185	0.557	-0.198
	End	1335	79.010	0.393	0.158

Med, KW lift	Lift-Off	2844	-26.979	0.836**	-0.054
	Mid	2844	-26.979	0.836**	-0.054
	End	1128	32.201	0.332	0.064
Med, Stoop, KW lift	Lift-Off	4307	-130.281	1.267**	-0.261
	Mid	4307	-130.281	1.267**	-0.261
	End	1598	117.341	0.470	0.235
Med, KW lift	Lift-Off	2968	-21.401	0.873	-0.043
	Mid	3954	-146.111	1.163**	-0.292
	End	1137	35.047	0.334	0.070
Med, TW lift	Lift-Off	2553	-55.389	0.751**	-0.111
	End	1245	62.060	0.366	0.124
Med, WC Lower	Lift-Off	1123	30.427	0.330	0.061
	Mid	1146	37.900	0.337	0.076
	End	3350	-150.749	0.985**	-0.302
Med, WF Lower	Lift-Off	2968	-21.401	0.873	-0.043
	Mid	1372	85.175	0.403	0.170
	End	4137	-133.801	1.217**	-0.268
Med, WK Lower	Lift-Off	2265	-55.072	0.666	-0.110
	Mid	1088	25.344	0.320	0.051
	End	3252	-152.968	0.956**	-0.306
Med, WS lift	Lift-Off	1208	54.077	0.355	0.108
	Mid	1210	54.335	0.356	0.109
	End	1335	79.010	0.393**	0.158
Med, WW lift	Lift-Off	1271	67.195	0.374	0.134
	End	1311	74.668	0.385**	0.149
Med, Asymmetric WW lift	Lift-Off	1951	-91.166	0.574**	-0.182
	End	1311	74.668	0.385	0.149
Med, WW lift	Lift-Off	1211	54.588	0.356	0.109
	End	1321	76.561	0.389**	0.153
Med, Coupling, WW lift	Lift-Off	2994	-20.258	0.881**	-0.041
	End	1211	54.588	0.356	0.109

Med, Frequency, WW lift	Lift-Off 1	1134	34.104	0.334	0.068
	Mid 1	1071	3.656	0.315	0.007
	End 1	1102	22.260	0.324	0.045
	Lift-Off 2	1198	51.507	0.352	0.103
	Mid 2	1071	3.656	0.315	0.007
	End 2	1224	57.671	0.360	0.115
	Lift-Off 3	1134	34.104	0.334	0.068
	Mid 3	1071	3.656	0.315	0.007
	End 3	1260	65.144	0.371**	0.130
	Lift-Off 4	1134	34.104	0.334	0.068
	Mid 4	1071	3.656	0.315	0.007
	End 4	1224	57.671	0.360	0.115
Med, Horizontal Reach, WW lift	Lift-Off	2451	-40.473	0.721**	-0.081
	End	1143	36.797	0.336	0.074
Med, WW lift	Lift-Off	1254	63.858	0.369	0.128
	End	2024	-77.827	0.595**	-0.156

** denotes the number taken as the maximum normalized risk value for each lifting task

Table 9.19 Pearson Product Moment Correlation R values stratified by demographic factor.

Demographic Factor	Sub-Category	Data Points	R	*p*-values
Sex	Male	3476	0.526**	<.0001
	Female	4224	0.472*	<.0001
	Unspecified	132	0.500	<.0001
Role in Company	Worker	4136	0.526	<.0001
	Supervisor	660	0.493	<.0001
	Employer	616	0.508	<.0001
	Health & Safety (H&S)	1232	0.440	<.0001
	Worker & Supervisor	132	0.450	<.0001
	Worker & Employer	88	0.524	<.0001
	Worker & H&S	176	0.561	<.0001
	Supervisor & H&S	176	0.440*	<.0001
	Employer & H&S	44	0.674**	<.0001
	Worker & Supervisor & H&S	220	0.510	<.0001
	Supervisor & Employer & H&S	44	0.530	0.0002
	Worker & Supervisor & Employer & H&S	44	0.586	<.0001
	NA	264	0.447	<.0001

Familiarity in Ergonomics	0-Not familiar at all	308	0.389*	<.0001
	1	748	0.588**	<.0001
	2	748	0.485	<.0001
	3	2464	0.479	<.0001
	4	2156	0.531	<.0001
	5-Very familiar	1408	0.465	<.0001
Sector	Accommodation & food services	704	0.460	<.0001
	Business, building and other support services	220	0.480	<.0001
	Construction	44	0.621	<.0001
	Educational services	1804	0.521	<.0001
	Finance, insurance, real estate and leasing	176	0.628**	<.0001
	Forestry, fishing, mining, quarrying, oil and gas	44	0.514	0.0004
	Information, culture and recreation	352	0.522	<.0001
	Manufacturing	660	0.458	<.0001
	Other services	1584	0.497	<.0001
	Professional, scientific and technical services	1408	0.535	<.0001
	Public administration	220	0.607	<.0001
	Trade	88	0.357*	0.0006
	Transportation and warehousing	440	0.515	<.0001
	Unspecified	88	0.585	0.0071†
Experience in Current Sector	1 year or fewer	1408	0.538**	<.0001
	More than 1 year but fewer than 5 years	2288	0.524	<.0001
	More than 5 years but fewer than 10 years	1496	0.517	<.0001
	10 years or more	2552	0.451*	<.0001
	Unspecified	88	0.285	0.0071†
Suffered a Low Back Injury that Resulted in Lost Time	Within the last 6 months	132	0.397*	<.0001
	Within the last year	132	0.445	<.0001
	Within the last 5 years	660	0.554**	<.0001
	Never	6820	0.500	<.0001
	Unspecified	88	0.335	0.0014†
Number of Employees in Company	20 employees or fewer	1408	0.474	<.0001
	More than 20 employees but fewer than 50 employees	616	0.600**	<.0001
	50 employees or more	5676	0.497	<.0001
	Unspecified	132	0.376*	<.0001

*/**'s = lowest/highest R value within a group †'s = insignificant correlation *p*-values