ABSTRACT

DO INDUSTRIAL BACK SUPPORT BELTS REDUCE STRESS IN ASYMMETRIC LIFTING?

by

Ryan Jamor Brown

The objective of this research is to determine the effects of wearing a back support belt during repetitive asymmetric lifting in terms of heart rate, blood pressure, static lift capacity, body discomfort rating and subjective rating concerning the effectiveness of a back support belt. The type of belt used in this study was of knit nylon and elastic construction designed for industrial use.

Eight female participants lifted a crate from the table to knuckle height at a rate of three lifts per minute for a period of 20 minutes; one set with wearing back support belt and one without back support belt. The weight of the box was then adjusted to participants' maximum acceptable weight of lift, which range between 9kg to 10kg. The overall average heart rate (HR) was reduced from 96.2 beats per minute (bpm) to 90.9 bpm when back support belt was worn, and the reduction was statistically significant ($P<0.05$). Average systolic and diastolic blood pressure reduced from 114/71 to 106/64 with back support belt, but reduction wasn't statistically significant. Body discomfort ratings and static lift capacity did not register any systematic or significant change. Subjective ratings strongly favored wearing of back support belt. Results supported the effectiveness of back support belts in reducing physiological stresses, possibly by increasing the structural support at the lower back and thereby reducing muscular activity in the lower back area.

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CHAPTER 1

INTRODUCTION

As per the latest Injury and Illness data published by the Bureau of Labor and Statistics, there were 559,000 cases of back-related (includes back, spine, spinal cord, sprains, and strains) injuries that resulted in days away from work in the U.S. in 2003. This constitutes 43% of all injury and illness cases (1.3 million) resulting in days away from work in 2003. Estimated back injuries cost the U.S. economy 20 to 50 billion dollars per year (NIOSH 1997). Companies have resorted to various measures, either in coordination with, or in place of sound ergonomic programs, for handling these increasing human and economic costs of back injury. The last two decades have seen an emergence of back belt use as a measure to combat back injury problems. From the most recent year for which data were available approximately four million back belts were purchased for workplace use in 1995 (NIOSH 1997). However, controversy regarding the effectiveness of back belts in preventing injuries to uninjured workers has still remained unresolved.

The National Institute of Occupational Safety and Health (NIOSH) came out as the leading critic on the use of back belts in occupational settings (NIOSH 1994). NIOSH does not recommend the use of back belts to prevent injuries among uninjured workers, and emphasizes that back belts do not alleviate the hazards to workers posed by repetitive manual material handling tasks. Instead, it recommends the development and implementation of a comprehensive ergonomic program to fight the back injury problem. This program should include appreciation of ergonomic principles of engineering, work methods, and administrative controls. NIOSH is not alone in questioning the effectiveness of back belts. Other institutes such as, the American Industrial Hygiene Association, the Bureau of Mines, the Army Office of the Surgeon General, the State of Washington Department of Labor and Industries, the Alberta Ministry of Occupational Health and Safety Canada, the United Brotherhood of Carpenters, and the Construction Safety Association of Ontario (Canada) have also raised similar concerns regarding the use and effectiveness of back belts (NIOSH 1997).

1.1 Background Information

The use of back support belts originated in medical settings. These belts, known as corsets and orthoses, are typically used to provide additional back support and restricting motions during rehabilitation of back injuries and back surgeries (Norton and Brown, 1957). A study on chronic back pain patients by Million et al. (1981) found significant improvement in patients wearing a corset when compared with those without a corset. It was theorized that lumbar support relieves back pain by restricting motion in several directions and reducing intradiscal pressure (IDP) in the lower spine (Morris and Lucas, 1963). They proposed that an extensor moment is developed by Intra-abdominal pressure (IAP) while wearing the support, which can reduce the IDP. IDP and spine compressive force is highly correlated to the risk of back pain and structural damage in lower spine. They found that an inflatable corset increases the resting IAP by 10-15 mm Hg.

The use of stiff leather belts in weight lifting exercise is also common. The torso-stabilizing effect and increased IAP from wearing a stiff leather belt are believed to reduce risk of back injury and increase lifting capacity during heavy weight lifting exercise (Harman et al., 1989 and Lander et al., 1990).

Since the last few decades the use of back belts has gained popularity in occupational settings. These back bets are also known as "back supports" or "abdominal belts". More than 70 types of industrial back belts are available in the market today (NIOSH 1997). They come in a variety of shapes and forms, ranging from the rigid leather belts used by weight lifters, to canvas corsets, to double layered elastic belts. The majority of the belts currently used in occupational settings, however, are double-layered elastic belts. The first layer is composed of stiff plastic, rubber, or steel sewn into the back of the belt to provide support to the lumbar region. It is wrapped about the torso at waist level, and usually secured with Velcro fasteners. The second layer is made of an elastic material, which can be stretched around the waist and secured again by Velcro fasteners. These belts may have some variations in terms of belt cut, color, presence or absence of shoulder straps, apron, etc., depending on the particular model of the belt or the company manufacturing the belts (Woldstad et al., 1998).

Several mechanisms of back injury reduction through the use back support belts in occupational setting have been proposed and investigated. One of the main risk factors for occupational back injury is high spine compressive force in the lower back region during the performance of heavy manual material handling (MMH) tasks. A large part of the spine compressive force arises due to the co-contraction of the lower back muscles while performing MMH tasks. The contracting forces from lower back muscles stabilize the torso and counterbalance the moment produced by the external loads placed on hands and the gravitational pulls on the body segments. It has been proposed that a back support belt can act as external passive stiffening device to the torso, and thereby it may reduce the need for the support generated by the lower back muscles. Additionally, if the presence of back support belt can help in producing higher IAP during manual activity, this also can help in reducing the counterbalancing moment needed to stabilize the torso, which ultimately would reduce the spine compressive force.

Other than these direct pathways, back support belt can alter the spinal motion at the lower back level, by directly restricting bending and twisting of the lower back during the performance of occupational tasks. Bending and twisting give rise to large spine compressive force; such a restriction would reduce the risk of lower back injury.

For manual lifting tasks, straight back and bent knee lifting method is often recommended over the bent back and straight knee method to restrict the bending at the lower back. Proper lifting technique, such as keeping the load close to the body and keeping the back straight as much as possible while lifting are included in most of the ergonomic training programs given to material handlers. However, how material handlers adhere to their training while performing occupational tasks is debatable. It is proposed that industrial back support belts may provide a constant reminder of keeping one's back straight and adopt proper posture while performing material handling tasks. This in turn can help in reducing the back injury rate throughout the industry in the long run.

Several large-scale epidemiological studies have been conducted to investigate the effectiveness of back support belt usage in reducing back injury rate in industry, but they provided contradicting results. Details of those studies are provided in the literature review section.

In laboratory setting, researchers have investigated effectiveness of back support belts by using various means. Spine kinematics, IAP, electromyography (EMG) of the lower back muscles, spine compressive force, spinal shrinkage, and spinal stiffness has all been evaluated in biomechanical studies to quantify the effectiveness of the back support belt. These biomechanical measurements reflect the localized physiological stresses due to task performance. The objectives of these studies were to find the effect of back support belt in terms of these stresses. Even though spine kinematics improved during industrial handling tasks while wearing belts, the rest of the biomechanical measures produced either contradicting or non-significant effects.

Most of the biomechanical studies that measured EMG used surface electrodes. The surface electrodes are placed on the skin surface directly over the muscle to be monitored. The electrodes can register the change in voltage while the muscle is activated and the voltage registered is approximately proportional to the intensity of the muscle activity. Surface electromyography produces reasonably good results for the muscles that are close to the skin surface, but ineffective to monitor the muscles that are placed deep inside the body cavity. Human lower back and torso are composed of complex groups of musculatures and many of the muscles groups are placed deep inside the body cavity. As a result it is not possible to monitor all muscle groups simultaneously.

Typically the functional joints in human anatomy are provided with redundant muscle groups and the lower back is no exception. The lower back has many more muscle groups than the minimum needed to stabilize it. Because of this redundancy, the problem of determining the internal forces that the muscle groups have to generate to balance an external applied load becomes a statically indeterminate problem. Various biomechanical modeling approaches have been developed to solve such a statically indeterminate problem employing various degrees of simplifying assumptions. As a result of this, the model output of spine compressive forces varies according to the assumptions underlying the model.

Unlike measuring localized biomechanical stress, systemic stress can be measured objectively in terms of physiological variables, such as volume of oxygen (VO_2), heart rate (HR), and blood pressure (BP). Oxygen is needed at the muscle site for energy metabolism to support sustained muscular work and hence VO_2 is directly proportional to the intensity of muscular work. As a result, HR is closely proportional to muscular work intensity for moderate to high intensity tasks. BP is measured in terms of diastolic (DBP) and systolic (SBP) blood pressure. DBP represents the peripheral resistance of the circulatory system and SBP represents the peak pressure developed during the contractile phase of the heart. BP is not proportional to muscular work intensity, but it is affected differently by static and dynamic characteristics of the task (Konz and Johnson 2004).

Back support belt studies that employed physiological stress measures also result in mixed results. One out of three studies found a statistical significant reduction of VO_2 while performing manual material handling task when wearing industrial back support belt (Bobick et al., 2001). Several studies employed HR as a measure of stress, and none found significant effects due to back support belts. Most of the studies used several different task frequencies, lifting methods and/or belt types as independent variables. Large numbers of independent variables and small numbers of experimental subjects could obscure the variation in physiological effect due to back support belt.

For example, Robinowitz et al. (1998) investigated four different conditions, straight back versus stooped back lifting styles with and without belt conditions for a manual material handling task performed by 10 subjects. The task was lifting a beer crate from floor to table level at a frequency of five lifts per minute. They found significant reduction of HR when performing the MMH task with stooped back lifting as compared to that during the straight back lifting, but no effect due to the back belt conditions.

In straight back lifting from ground level, thigh and hip muscles must perform extra work to lower and raise a larger body mass along with the load being lifted. It is well known that this extra muscular work significantly increases the muscular work intensity and consequently metabolic load. This variability due to lifting style may have confounded the variability due to the wearing and not wearing the back support belt between subjects. The authors also did not provide the heart rate counts in two belt conditions and only reported that the HR and HR variance were not affected by belt conditions.

Marley and Duggasani (1996) investigated the difference of physiological costs for eight subjects while wearing and not wearing back support belt for a task combinations of two weight levels (7 and 14 lbs) combined with three lift frequencies (3, 6 and 9 lifts/min) for a lifting task from floor to table height. They also did not find any significant difference due to back support belts in terms of VO_2 and HR. In addition, using a small number of experimental subjects may obscure the variability due to the interaction of other independent variables.

In a study conducted on thirty healthy adult subjects (five females, twenty five males), Bobick et al. (2001) investigated physiological effects of wearing three different types of back support belts. The subjects were randomly divided into three groups of 10 subjects and were assigned to each experimental condition. The test involved lifting 9.4

kg box, 3 times per minute, starting 10 cm above the floor, and ending at 79 cm with a 60-degree twist to the right. Even though there was no other factor than belt wearing, no significant difference in terms of physiological responses, except VO_2, were noticed. The average VO_2 consumption was significantly reduced ($p = 0.03$) from 0.762 liter/min to 0.711 liter/min while wearing back support belt, and the average reduction of 0.762 – 0.711 = 0.051 liter per minute, which was approximately 20% of the resting oxygen consumption rate (0.284 l/min) of the experimental subjects. Even though this significant reduction of VO_2 due to back support belt was obtained, the authors did not find significant reduction in HR and attributed the absence of this effect due to the individual variability in HR. They recommended using higher intensity handling tasks in future studies, which may make changes in HR more obvious.

For static physical exercise, such as holding a load in hand, muscles remained in contracted state for the duration of the exercise. This sustained muscle contraction poses a physical restriction to the blood flow through nearby blood capillaries and as a result a sharp increase in blood pressure is often associated with static muscular work. But for dynamic work, which involves periodic contraction and relaxation of muscle groups, elevation of BP is not that obvious. For a dynamic material handling task, Marley and Duggasani (1996) found a significant increase in both the SBP and DBP when wearing a back support belt, but Bobick et al. (2001) did not find any such effect. For statically holding an 11 Kg load in hand, Rafacz and McGill (1996) found a significant increase in DBP while wearing back support belt.

CHAPTER 2

LITERATURE REIVEW AND OBJECTIVE

Literature review on studies related to industrial back belt is presented in four broad categories: epidemiological studies, biomechanical studies, physiological studies and psychophysical studies.

2.1 Epidemiological Studies

The epidemiological studies monitored two large industrial groups - a group of interest using back belt as opposed to a group without the use of back belts, and are studied over time. Various outcomes were compared at the end, such as injury statistics, absenteeism, and subjective surveys.

In a cohort study, Kraus et al. (1996) examined the workplace injury history of 36,000 workers of a national home improvement retailer, who worked at its 77 California stores for six years to determine the effect of a change in company's back belt use policy on the occurrence of work related low back injuries. The back belts used for the study were made of Lycra material, most with and some without shoulder straps. The study found that before the implementation of a company wide consistent back belt use policy, the workers had sustained about 31 back injuries per 1 million work hours. After implementation, this injury rate dropped to 20 back injuries per 1 million work hours. The authors concluded that the use of back belts did not have any harmful effects, and showed a substantial 34% reduction in back injury rates. During the study prevalence surveys were conducted to observe the use or non-use of back belts among employees in

1993 and 1994, which showed a high rate of compliance with company policy on the use of back belts.

Mitchell et al. (1994) performed a retrospective investigation to determine the effectiveness of the back belts by observing 1,316 warehouse workers performing manual material handling tasks at a US Air Force base over a period of 7 years. Initially a leather belt was used for the study, which was later replaced by a commonly used softer canvas back belt. Of the 1,316 workers, 38 workers were required to wear back belts, 172 workers voluntarily decided to wear back belts, and 1,106 did not wear back belts. Of the 1,316 warehouse workers, majority were baggage handlers and supervisors who perform such duties when necessary. The rate of lost workdays decreased among the workers wearing back belts as compared to the workers who did not use back belts. The results are in agreement with the findings of Kraus et al. (1996). However the cost of treating workers who were injured while wearing back belts was about 1.58 times greater than the cost of treating workers who were injured while not wearing back belts, which questioned the cost effectiveness of back belt use. The above study, however, had two major limitations. Firstly, the change from a leather belt to a canvas belt might have influenced the results to some extent. Secondly, it was not known if all the workers wearing back belts were doing the same type of manual lifting. Thus presence of different tasks could have influenced the result in either way.

Wassell et al. (2000), conducted a prospective cohort study for NIOSH involving 9,377 material-handling employees in 160 new retail merchandise stores in 30 U.S. states, over a period of two years (from April 1996 to April 1998), to determine the effects of wearing back belts on the incidence of back pain and workers' compensation claims for material-handling back injury requiring medical care. Of the 160 stores, 89 stores required their employees to wear back belts during material-handling activities, while the remaining 71 stores provided back belts only to those employees who volunteered to use them. The back belt used for the study was constructed of stretchable nylon material with Velcro ends and mesh in back with no shoulder straps. Based on the results the authors concluded that back belts neither had any significant effect in the prevalence of back pain nor had any significant effect in back injury claim rates, among those employees who reported wearing them usually every day and those employees who never wore them. The authors did not find any significant effect in the prevalence of back pain or in back injury claim rates among the stores, which adopted mandatory belt-use policy (14.7 back injury claims per 1 million work hours), and the stores, which had voluntary belt-use policy 16.2 back injury claims per 1 million work hours. As mentioned earlier, the study conducted by Kraus et al. (1996) assumed that the workers complied with the company policy on back belt use throughout the length of the study. Wassell et al. (2000) tried to minimize this limitation by directly questioning employees about their belt-wearing habits during follow-up interviews. Though there are limitations with this approach, for example employees lying about their belt-wearing habits. However, of the 9,377 employees studied, 3,066 employees could not be contacted for the follow-up interviews, which is a limitation of this study. Thus based on the above studies only, it is not quite possible to comment on the effectiveness of workplace use of back belts, which calls for further investigation.

2.2 Biomechanical Studies

Researchers have conducted a number of biomechanical studies in laboratory settings to determine the effects of back belts on intra-abdominal pressure, spinal compression forces, lower limb kinematics, electromyography (EMG) of lower back muscles, spinal stiffness and spinal shrinkage. Some of the important studies are discussed below.

In a laboratory study, Magnusson and Pope (1996) investigated whether back belts had any positive biomechanical effects on twelve subjects (five males, seven females) with no previous history of low back problems, while lifting a 10 lb weight from the floor to a height of 72 cm twice per minute. The authors observed a loss of height (suggesting spinal shrinkage) when the load was lifted. The authors also observed that the height loss was less if the subjects wore back belts. Furthermore, average percent of individual maximum contraction used when lifting with the back supports was lower, that is, each subject used less of his or her maximum possible lifting effort when wearing the back support. Based on these observations, they concluded that back belts had a load relieving effect on the spine.

In another study conducted on fifteen healthy adult males, Granata et al. (1997) observed the biomechanics of lifting for various belt conditions - no belts, elastic belt, leather belt, and orthotic belt. The results showed a considerable reduction in the range of motion, extension velocities, and accelerations associated with the trunk during lifting exertions while wearing back belts. Based on previous research, which associates spinal loads and risk of low-back pain with trunk motions and postures, the authors concluded that back belts might possibly reduce the risk of low back pain by reducing trunk flexion angles. Yet the reduction in trunk flexion angles was achieved with a corresponding increase in pelvic angles. This may give rise to problems related to the pelvis. Moreover, though the use of back belts was associated with an overall reduction in spinal load, some subjects responded with increased spinal load. This indicates that individual differences between subjects should be considered while arriving at decision about the back belt use or selecting the type of back belt. The study also found that, of the three belt-types used, the elastic belt affected trunk motion and spine load the most. However, the elastic belt was much wider than the other belts, expanding from the pelvis to the thoracic region of the spine. The other belts resided between the thorax and the iliac crest. Hence the author speculated that the taller belt might be more effective as it could be forcing the trunk to act as a unit, thereby reducing the coactivity and the resulting trunk loading.

Woldstad et al. (1998) conducted a study on sixteen healthy subjects (eight males, eight females) with no history of back pain or injuries, to determine the effects of back belt on posture, strength, and spinal compressive force during static lift exertions. The authors noticed a reduction of about 4 degrees in axial twist of the torso for calf height asymmetric exertions when the subjects wore back belts. The authors concluded that this reduction in asymmetry would increase the National Institute of Occupational Safety and Health's (NIOSH) recommended weight limit (RWL) by approximately 1-1.5%, the magnitude of which is not significant enough to reduce the risk of injury for most workers using back belts. The authors also found a reduction of 285 N in the compressive force in lumbar spine, which is in line with the observation made by Magnusson and Pope (1996). Nonetheless, this average reduced only about 9%; the authors did not find the reduction significant enough to reduce the risk of injury for most workers using back belts.

In another laboratory study, Rabinowitz et al. (1998) observed 10 healthy male subjects with no history of back pain or injury, performing a repetitive lifting task for 15 minutes under four conditions- squat or stoop lift with or without back belt. Each subject lifted about 20% of his body weight from floor to a height of 75 cm and back to floor per lift with a frequency of 5 lifts per minute. During the study the authors observed a significant spinal shrinkage when the subjects performed the lifting task irrespective of lift type (squat or stoop). This spinal shrinkage was large as compared to shrinkage measured during quiet standing. The authors also noted that the presence of back belts did not have a significant load relieving effect as found by Magnusson and Pope (1996), discussed earlier. Thus the authors concluded that not lifting at all is always better than lifting even if it involves safe lifting techniques and/or back belts usage. Consequently, eliminating the need to lift through automation or mechanization of operation should always be the first priority in the ergonomic redesign process.

A study conducted by Miyamoto et al. (1999) involving seven healthy adult male volunteers with no previous history of back pain, to demonstrate the biomechanical effects of back belts while lifting, concluded that the presence of back belt did not have a significant effect on the peak intra-abdominal pressure and maximum isometric lifting capacity. On the contrary, the intra-muscular pressure of the erector spinae muscles did show an increase for the lifts performed while wearing the back belts. Assuming that increased intra-muscular pressure of the erector spinae muscles stabilizes the lumbar spine, the authors concluded that wearing back belts might help in stabilization during lifting exertions.

Ivancic et al. (2002) performed tests on 10 subjects (nine males, one female), with no previous history of back problems, to determine the effects of back belt on spine stability and loading. Subjects performed isometric trunk flexion, extension, and lateral bending to the left at 35% of their maximum effort, at 0% and 80% of their maximum internal abdominal pressure, with and without a 10 cm wide and 8 mm thick nylon weightlifting belt. Based on the study, the authors concluded that the back belt did not have any significant effects on L4/L5 joint compression force, which is in agreement with the observations made by Rabinowitz et al. (1998). In addition, the authors did not find any significant effect of belt on active spine stability, though the passive stability showed some improvement with back belt use.

2.3 Physiological Studies

Researchers have performed various physiological studies in the laboratories to determine the effects of back belts on oxygen consumption, heart rate, respiration rate and blood pressure, some of which are discussed below.

In a study conducted by Marley and Duggasani (1996), involving eight college-age males performing manual lifting of 7 kg and 14 kg loads at frequencies of 3, 6, and 9 lifts per minute, with and without back belts, no significant changes were observed in the heart rate, respiration frequency, and total energy expenditure with the use of back belts. Nevertheless, significant rise was found in the systolic and diastolic blood pressure while performing all lifting tasks with back belts. Therefore, the authors concluded that the use of back belts might have adverse health effects on workers who are hypertensive, near hypertensive, or who have a compromised cardiovascular system.

Soh et al. (1997) conducted a study on eleven male students with no previous history of back problems to evaluate the change in the frequency of respiration during a repetitive lifting task done while wearing back belts. The task involved lifting a bucket weighing nearly 12 lb, turning 45 degrees to left, and placing it at a height of 60 cm, 10 times per minute for approximately 6 minutes, for various belt conditions - no back belt, a nylon back belt, an inflatable back belt, and an elastic vest. The results revealed that the respiration rates during a lifting task increased while wearing a back belt as compared to the respiration rates while not wearing a back belt. In spite of this, the difference was statistically significant only for the lift performed while wearing a nylon belt as compared to lift performed without wearing any back belt. Based on previous studies the authors attributed the increase in respiration rate to an increase in intra-abdominal pressure and reduction of abdominal distension. The authors felt that because the nylon belt was more rigid as compared to the other belts, it prevented abdominal distension to a greater extent, and had a greater effect on respiration rate.

In the study conducted by Rabinowitz et al. (1998) discussed earlier, the authors did not find any significant difference in heart rate and blood pressure increase when the subjects wore back belts. These observations agree with the observations made by Marley Duggasani (1996), discussed earlier, in terms of the effects of back belts on the heart rate, but fail to agree on their effects on the blood pressure.

In a study conducted on thirty healthy adult subjects (five females, twenty five males) with material handling experience of at least 3 months, Bobick et al. (2001), investigated the effects of wearing back belts on subjects' heart rate, oxygen consumption, systolic and diastolic blood pressure, and respiratory frequency during asymmetric repetitive lifting. The test involved lifting 9.4 kg box, 3 times/minute, starting 10 cm above the floor, and ending at 79 cm with a 60-degree twist to the right. Each test session lasted for 30 minute with 15-minute rest period in between. Each subjects performed six sessions, three with belts and three without. The use of back belts did not have a significant effect on the overall mean values for heart rate, systolic and diastolic blood pressure, and respiratory frequency. The study agrees to the conclusions derived by Rabinowitz et al. (1998) in terms of the effects of back belts on the heart rate and blood pressure, but fails to agree with the conclusions made by Soh et al. (1997) in terms of their effects on respiratory frequency. The study, conversely, revealed a significant reduction in oxygen consumption with the use of back belts. It is well known that oxygen consumption is linearly proportional to the intensity of muscular work and it is the most reliable physiological measure to quantify dynamic muscle activity. In the this study the average oxygen consumption reduction was about 20% of average resting value, which indicated a potential reduction in total aerobic muscular work due to wearing of belts. Moreover, the authors summarized that no beneficial or detrimental effects could be ascertained from the study, probably due to no significant changes in the heart rate. Heart rate is a good indicator of the intensity of muscular work, but only when the work intensity is more than 40% of one's aerobic capacity. The average heart rate recorded in the above study was about 92 beats/min, which indicates the work intensity being quite light. Furthermore, the resting heart rate for individuals varied considerably, suggesting that a measure of heart rate elevation during work would have been more conclusive than absolute heart rate used in the study. The individual variability of heart rate can considerably influence the back support effect in the statistical tests.

2.4 Psychophysical Studies

Psychophysical studies determined the effects of back belts on the subjective perception of safety, maximum acceptable weight to lift, and discomfort ratings.

In a laboratory study, McCoy et al. (1998) observed twelve adult male college students performing lifting operations under three belt conditions - no belts, inflatable air belt, and elastic belt. Subjects lifted about 13% more weight while wearing the air belt and about 19% more weight while wearing the elastic belt as compared to the weight they lifted without the belt. The study also revealed that about 67% of the subjects preferred to perform the lifting operations while wearing either of the two belts as opposed to not wearing any belts. The above observation supports the concern raised by the NIOSH (1994) Working Group that lifting belts may alter a worker's perception of their capacity and cultivate an undesirable sense of safety. The study conducted by Mitchell et al. (1994), discussed earlier, further fuels the concerns raised by NIOSH. Though the authors found a decrease in the rate of lost workdays among the workers wearing back belts, the cost of treating workers who were injured wearing back belts was greater than that required for treating workers who were injured while not wearing back belts. Higher treatment cost among the workers wearing back belts indicates that their injuries were more severe, which further indicates that the use of back belts may have fostered a false sense of safety among the workers leading to overexertion.

The twelve subjects of the laboratory study administered by Magnusson et al. (1996) gave a subjective impression of increased support and enhanced lifting capacity with the use of back belts. Their perception agrees with the effects felt by the subjects of studies conducted by McCoy et al. (1988), explained earlier.

Marley and Duggasani (1996), during their study discussed earlier, concluded that subjects did not perceive less effort in lifting while wearing the back support. Consequently, the authors believe that an individual would not select greater loads or otherwise over-lift while wearing a back belt as opposed to not wearing a belt. Similar behavior was observed among the subjects participating in the study conducted by Rabinowitz et al. (1998), discussed earlier. The authors noted that belt use was not associated with any differences in perceived exertion. These observations are in contradiction to those made by McCoy et al. (1988), and questions the validity of concerns raised by NIOSH that back belts may foster false sense of protection among their wearers leading to back problems due to overexertion.

As per a survey conducted by Miyamoto et al. (1999) among the weightlifters in Japan, the majority of the lifters perceived enhanced stability and stiffness in their backs when they used the belts during lifting. At the same time, the weightlifters felt that it requires experience to get a positive effect from wearing back belts.

A NIOSH sponsored study conducted by Wassell et al. (2000), discussed earlier, found a lack of compliance among the employees with the store belt-wearing policy. Though it was mandatory to wear back belts during manual material handling tasks in these stores, only 58% of employees admitted wearing back belts everyday, while 28% admitted never wearing them. In the stores with voluntary belt-use policy, 33% employees reported wearing belts everyday while 56% never wore them. This suggests that a majority of employees may not prefer to wear back belts, unless they are forced to do so. Discomfort can be speculated as one of the reasons for employees not wearing them.

In the study conducted by Rabinowitz et al. (1998), though the subjects perceived the squat lift with back belt to be the safest of all lifting conditions (squat and stoop lift with and without back belts); five out of ten subjects considered lifting with the belt as their least preferred lifting method. Therefore, perception of safety may not necessarily encourage the use of back belts. Again, discomfort can be a cause influencing their decision.

During the study conducted by Bobick et al. (2001), subjects wore the back belts tightly, but not tight enough to be uncomfortable, as per manufacturers' instructions. None of the subjects complained about discomfort during or after any of the six 30-minute sessions. As a result, subjects may prefer to wear back belts if they are required to wear them for smaller sessions, instead of continuous use.

Chen (2003) conducted a study on twelve male Chinese university students, with no prior history of back problems, to determine the effect of the tightness of back belts on the psychophysical determination of lifting capacities. The task involved perceiving maximum acceptable weight limit for frequent lifts (4 lifts per minute) and infrequent lifts (one time maximum) from floor height to knuckle height and from knuckle height to shoulder height under various belt conditions- no belt and varying belt tightness (15 mm of Hg, 20 mm of Hg, and 25 mm of Hg). An elastic belt was used during this study. The results revealed that belt tightness significantly increased the lifting capacity only when the lifts were performed infrequently (one time maximum) from the floor height to the knuckle height with the belt-tightness of 25 mm of Hg. Excluding if the same task were performed frequently (4 lifts per minute) with the same belt tightness, the maximum acceptable weight limit was found to be the lowest. Also, the presence or tightness of belts did not have any significant effect on perceived lifting capacity for lifts performed from the knuckle height to the shoulder height irrespective of lifting frequency. Likewise, the belts did not have any protective effect on trunk, if they were worn loosely. On the other hand, most subjects reported extreme discomfort, especially in abdominal regions, when the belt was worn at 25 mm of Hg tightness. As a consequence, the effectiveness of back belts is highly questionable for repetitive tasks performed below knuckle height and any tasks performed above knuckle height, irrespective of lifting frequency. The authors also concluded that it was necessary to find a trade-off in belt tightness between subjective preference and lifting capacity.

2.5 Objective

One commonality of the industrial tasks that has been simulated in three physiological studies described above involved lifting of load from floor to table level. Lifting load from floor level dictates extreme forward bending, which should actually be resisted by the passive stiffness of the back support belt. While the subjects are bending below their waist level to pick up the load, they will do additional work to overcome the resistance provided by the belt. Lift originating at the floor level involves large shear load at the lower back and a flexible belt is ill equipped to support such a shear load. But the back support belts may otherwise provide support to the lower back by providing passive stiffness, while handling loads in erect to mildly flexed torso posture.

Material handling situations that requires mildly flexed torso are not uncommon in industry. Majority of the grocery store check-stand operators, workers who stock items on the shelves in grocery or other stores, package delivery workers and warehouse workers perform majority of the material handling task where the lift origination point is near waist level or higher. These tasks involve little or no bending of the back.

The objective of this study is to investigate the effectiveness of industrial back support belt in reducing physiological stresses for an asymmetric manual material handling task performed with mild flexion at the waist level. This study compares the physiological stress during the task performance by measuring heart rate, blood pressure (Systolic and Diastolic pressure), and static lift capacity with support belt versus without support belt. In addition, psychophysical stresses in terms of perceived exertion and body discomfort ratings, and subjective preference of belt use will also be collected through questionnaires.

CHAPTER 3

EXPERIMENTAL METHOD AND DATA COLLECTION

3.1 Participants

A search for volunteer participants was conducted through flyers posted in notice boards in and around NJIT campus. A total of eight female participants were selected on a first come first serve basis with no known musculoskeletal or cardiovascular history. The participants were informed about the nature of the experiments and were required to sign off an informed consent prior to their participation of the experiment. The informed consent form described briefly the objective of the study, methods and the confidentiality clause. Appendix A includes the informed consent form used in this experiment. The volunteers were paid $10.00 per hour for their participation in the experimental trials.

Table 3.1 Anthropometric and Demographic Data of Participants

Participant	Age (year)	Height (cm)	Weight (kg)
1	21	160	62
2.	18	183	71
3	25	150	75
4	20	163	65
5	48	170	70
6	24	164	90
7	18	184	65
8	23	150	96
Average	25	166	74
Standard deviation	10	13	12

The participants came from various walks of life: student and staff members of NJIT, material handlers, check-stand operators, and basketball athletes. Table 3.1 lists the participants' anthropometric and demographic data. The mean (standard deviation) of age, height, and weight were 25(10) years, 166(13) cm, and 74(12) kg, respectively.

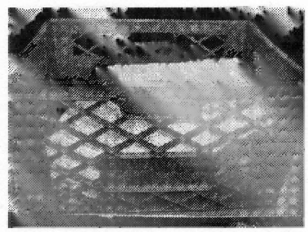
3.2 Experimental Setup

Each volunteer participated in two experimental sessions - with and without belt in randomized order, lasting for about one hour on two separate days. The belt and no-belt sessions were separated by at least two days of interval between them, to avoid any carryover effect of learning and training of the experimental task. The average time between sessions for all participants was four days.

The belt used in the experiment was an elastic industrial back support belt (Safe-T-Lift, FLA Orthopedics, Inc.). The inner layer of the belt was made of breathable fabric with velcro closure. The width of the belt was 20 cm at the lumbar region, and contoured down at the front to 14 cm. Four stiff plastic inserts with rubberized friction surfaces were provided around the lumbar region of the belt to prevent rolling up of the belt during exercise. There were two 10 cm wide elastic tensions at the two sides which when pulled and attached to the Velcro in the front provided the required belt tension force. Small, medium or large sizes of the belt were used according to the waist measurement of the participants.

The experiment was conducted at the Ergonomics Laboratory of the Industrial and Manufacturing Engineering Department of NJIT. The experimental setup was consisted of a table set at 80 cm height, and a small platform set at 31 cm height from floor (Figure 3.1a). These heights corresponded to the average female standing elbow height of 99.79 cm and average female sitting knee height 51.44 cm (Konz and Johnson, 2004) after adjusting for the handle height of 20 cm of a plastic milk crate. The plastic crate had smooth cut out handles and was used as the load-carrying device in the experiment (Figure 3.1b). Participants, standing on the floor in front of the table transferred the plastic crate (30.48cm x 30.48cm x 25.4cm) from the table to the platform at a rate of three lifts per minute for 20 minutes. The frequency of the lifts and the duration of the exercise were maintained by a computerized digital timer. The timer program displayed the elapsed time of the exercise on a video display terminal and beeped every 20 seconds, indicating the start of lift.

(a)



(b)

Figure 3.1 Experimental setup: (a) the relative orientation of the table and platform and (b) the milk crate used for load transfer.

The horizontal distance of the move was approximately one meter. The table, platform and the floor were marked with masking tape to control the start and end position of the crate, and the position of the participant (Figure 3.1). The participants were instructed not to shift their feet during the lifts. The orientation of the table and platform required an approximately 60 degrees angle of axial twist for the participants. The crate was brought back to table and positioned at the starting position by a research assistant at the end of each transfer by participants.

The weight of the crate was adjusted to the maximum acceptable weight limit (MAWL) of the participant by placing sand bags in it. The MAWL for each participant was used versus a fixed weight, because the MAWL allows participants to lift a weight based on their load carrying capacity and thus loading each participant according to their capacity. MAWL for each participant was determined by trial on the first day of the experimental sessions. At the start of the trial for MAWL, the participant was instructed to assess her maximum load limit that she would be able to handle for 1 hour continuously at a rate of 3 lifts per minute. The participant would perform the experimental task of transferring the crate from the table to the lower platform without knowing the weight of the crate. The starting weight of the crate was randomly varied between 9 to 13 kg. During this trial, sand bags with random weights were introduced or removed from the crate at the participant's preference. After 3 to 5 minutes of such trials, when a participant agreed upon her MAWL, the loaded crate was weighed using a Detecto Scale by the Lafayette Instrument Company, and was recorded as her MAWL. In both belt and no-belt session this MAWL was used as the load amount of the material handling task.

3.3 Data Collection

Omron digital BP monitor was used to record diastolic blood pressure (DBP) and systolic blood pressure (SBP) at rest and immediately after the completion of the 20 minutes of the experimental task. The device automatically inflates and deflates the cuff around the upper arm and displays the DBP and SBP.

The heart rate was recorded at rest, during every 1 minute for 20 minutes of total exercise time, and during the recovery period. Cateye PL-6000 heart rate monitor was used to record the heart rate. It uses an optical sensor attached to the earlobe to count the pulse rate. The instrument can store the time varying heart rate data in its memory, which are later displayed and recorded.

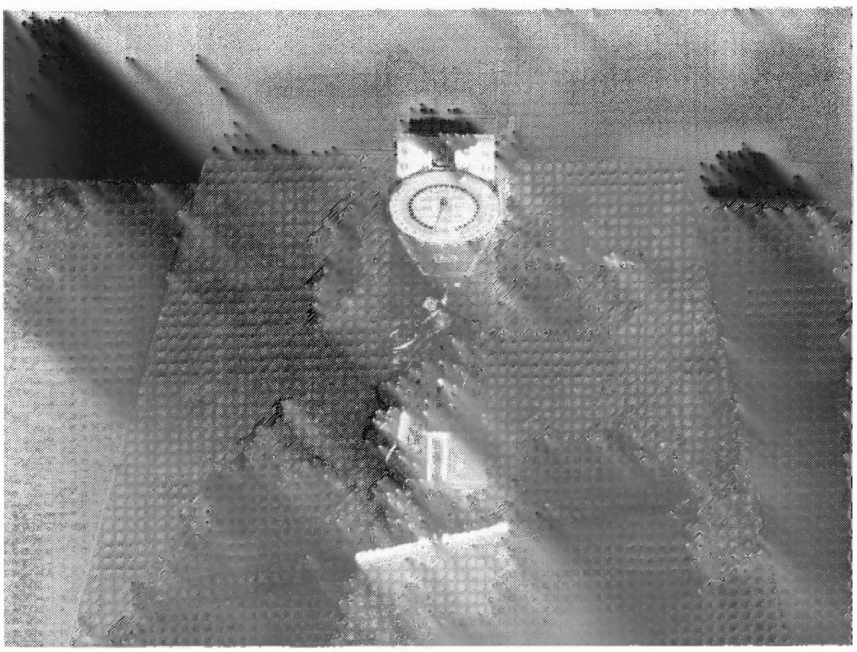


Figure 3.2 Static lift capacity device.

The static lift capacity of the participants was determined by the Static Lift Capacity Device (Figure 3.2). The device consisted of a spring-loaded scale, one end of which is fixed to the wooden platform. The other end of the scale was attached to a padded 1-1/2 inch diameter steel handle via an adjustable length steel cable and pulley system. To measure the lift capacity of a participant, the vertical position of the handle was adjusted to the knee height of the participant. The participant stood on the platform and exerted her maximum two-handed pull force on vertically on the handle. The participants were instructed to gradually build up their pull force and would be able to hold their maximum force for about three seconds. They were free to choose lifting posture during this measurement. The indicator of the scale recorded the maximum pull force.

The static lift capacity was measured for both belt and no-belt conditions in the beginning of the exercise before the experimental lifting task begun and then at the end of the experimental task after blood pressure and heart rate were measured. Ten minutes of recovery time was allowed after the lift capacity measurement before the experimental task was started.

A diagram (Appendix B) was used to rate of body discomfort in a scale of 1 to 10 (1 representing no discomfort and 10 being maximum discomfort) immediately after the completion of each exercise session for belt and no-belt condition. Using the diagram, participants circled the number representing their body discomfort corresponding to each body regions.

A set of questionnaire was prepared to assess the back support belt effectiveness similar to the questionnaire used in McCoy et al. (1998) study. It included seven questions (Appendix C) and participants rated them in a 1 to 5 scale at the completion of both experimental sessions.

3.4 Experimental Procedure

On the first day of the experimental sessions, the participant filled out the Ergonomic Lab Sign-up sheet with their name, age, weight, height, and occupation. A preliminary walk through was conducted about the experiment, where the participant was briefly informed about the objective of the research and the experimental procedure. The consent form (Appendix A) was read to the participant and she was informed that she could discontinue the experiment at any time. After signing of the consent form, the experimental procedures for each of the two sessions were conducted in the following sequence:

1. Participant's resting blood pressure and heart rate were measured and recorded.
2. The participant was asked to use the Static Lift Capacity Device to determine her static lift capacity.
3. The participant's maximum acceptable weight limit (MAWL) was determined using the procedure as described in section 3.2. Once the MAWL is determined, the participant received 10 minutes of recovery time to allow her stamina and strength to recover.
4. The participant was assigned randomly to belt or no-belt condition. For belt condition, the participant was given help to wear the belt according to the manufacturer's instruction.
5. The heart rate monitor was set to record heart rate at an interval 1 minute for 20 minutes and the sensor was attached to the participant's earlobe.
6. The participant performed the repetitive material-handling task following the computer beeps at 20 seconds interval. After 60 such transfers were complete, at the end of 20 minutes the exercise was stopped.

7. Immediately after the exercise, the participant was seated at the table adjacent to the experimental area so her final blood pressure and recovery heart rates can be collected.

8. The post exercise static lift capacity of the participant was conducted and recorded.

9. The participant filled out the body discomfort diagram.

At the end of both sessions only, the belt effectiveness questionnaire was administered. The data collection form was used to facilitate this methodical sequence (Appendix D).

CHAPTER 4

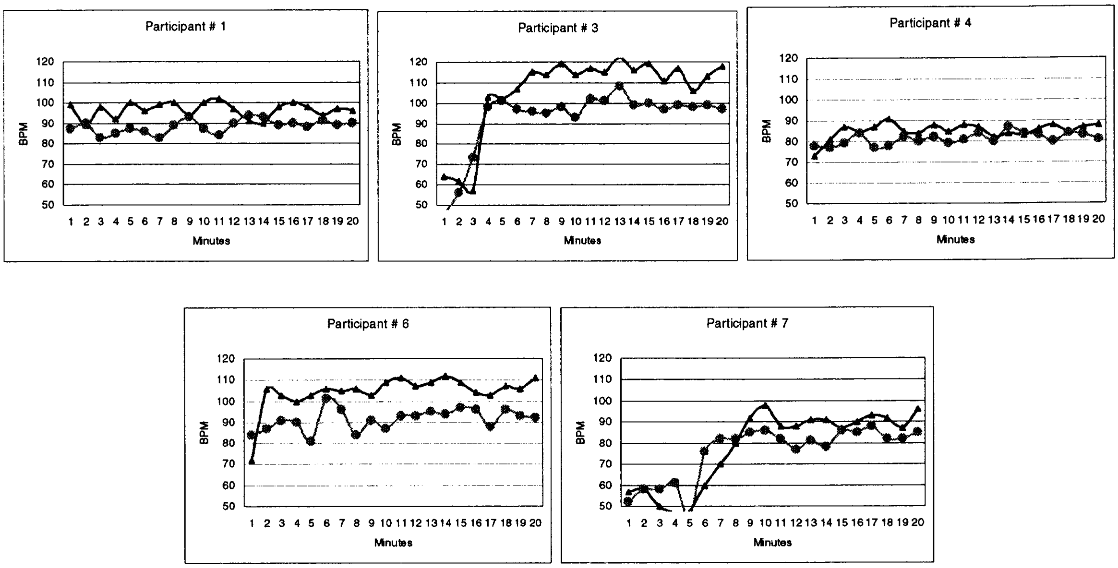
RESULTS AND ANALYSES

The results of the physiological and psychophysical effects of back support belt in performing the manual material handling (MMH) task are presented in terms of heart rate, blood pressure, static lift capacity, rate body discomfort, and subjective preference.

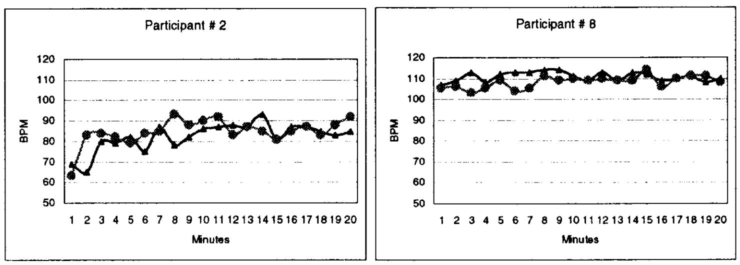
4.1 Heart Rate

The heart rates of the participants during the performance of the 20 minutes MMH task with and without belt are presented Figure 4.1. The plots show that out of the eight participants, five recorded a systematic reduction in heart rate while wearing back support belts (Figure 1a), two participants showed practically no change (Figure 1b) and one participant experienced a increase in heart rate while wearing the back support belt. A reduction in heart rate while wearing the back belt indicates reduction of physiological stress during the exercise session, and supports a positive contribution of the back support belt during the material handling exercise in reducing the physiological cost of work.

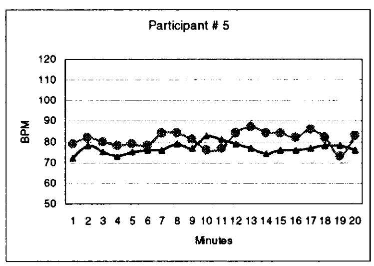
From the start of the exercise, heart rates of the participants took about 10 minutes to stabilize to the exercise intensity (Figure 4.1). Hence, the average working heart rates of the participants were calculated by averaging the last 10 minutes heart rate data, which is presented in Table 4.1. In terms of the average heart rate, only one participant experienced an elevation of heart rate while wearing back support belt. The other seven



(a) Heart rate decreased with belt



(b) Heart rate remained unchanged with belt



(c) Heart rate increased with belt

Figure 4.1 Participant's heart rate while performing the MMH task. (●-with belt, ▲-without belt)

participants experienced reduction heart rate compared to no-belt condition or remained unchanged. The overall average heart rates for all participants were 96.2 and 90.9 bpm for no-belt and belt conditions respectively, which was an average reduction of 5.3 bpm or a reduction of 4.9% from the no-belt condition.

4.1.1 Statistical Test of Difference in Heart Rate

To verify the statistical significance of this reduction, a paired *t*-test of the difference is conducted with test hypothesis: $H_0: \mu_1 - \mu_2 = 0$; $H_1: \mu_1 - \mu_2 > 0$, where, $\mu_1 - \mu_2$ is the difference in the average heart rates with no-belt and belt conditions, respectively.

Test statistic: $t' = \dfrac{\bar{d}}{s_d / \sqrt{n}}$, where $\bar{d}$ and s_d are the sample mean and standard deviation of the n differences. Probability $p = P[t > t']$ for a *t*-distribution with df of n-1, gives the p value of the test.

Table 4.1 Average Heart Rates During the Last 10 Minutes of the Experimental Manual Material Handling Task with No-Belt and Belt Conditions

Participant	Average heart rates (bpm)		Reduction in heart rate	
	No-belt	Belt	BPM	%
1	96.3	89.8	6.5	6.7
2	86.3	86.3	0.0	0.0
3	115.4	100.0	15.4	13.3
4	85.8	82.7	3.1	3.6
5	77.2	82.2	-5.0	-6.5
6	107.9	93.7	14.2	13.2
7	90.3	82.6	7.7	8.5
8	110.4	109.7	0.7	0.6
Average	96.2	90.9	5.3	4.9
Standard	13.7	9.8	7.1	6.9

From Table 4.1 $\bar{d}$ = 5.3, s_d = 7.1 and n = 8, which gives t' = 2.13, and p = 0.035 with df = 7. H_0 can be rejected with a p-value of 3.5%. Thus the above analysis proves a significant decrease (p= 0.035) of heart rate for the MMH task while wearing a back support belt.

4.1.2. Percent Maximum Heart Rate Range Required by the MMH Task

Percent of maximum heart rate range (%HR) utilized during a manual task can be measured by the following equation:

$$\%HR = \frac{HR_{work} - HR_{rest}}{HR_{\max} - HR_{rest}} \times 100$$

where HR_{work}, HR_{rest} and HR_{max} are the average heart rate during exercise, heart rate while at rest, and maximum heart rate of an individual, respectively. HR_{max} can be roughly estimated by subtracting a person's age from 220 (Astrand et al., 1973).

The numerator of Equation (1) denotes the rise in HR due to performance of work from resting heart rate, and the denominator denotes the maximum range of (reserve capacity) heart rate for the individual from the resting. The computation %HR utilized for no-belt and belt conditions are presented in Table 4.2. The resting heart rates for an individual were recorded on the day of the experimental trials for no-belt and belt conditions and the HR_{max} have been calculated from the age of the participants.

In terms of %HR, when wearing belt, five participants utilized less of their maximum heart rate range, two participants' used greater and for one participant there is no change. Overall average reduction of %HR was 2.6%. A matched pair t-test, similar to section 4.1.1 produces the following result for %HR: $\bar{d}$ = 2.6, s_d = 6.9 and n = 8, which gives t' = 1.138, and p = 0.146 with df = 7. H_0 cannot be rejected with a critical p-value of 5% and we can conclude that the difference in mean %HR between the two conditions is not significantly different.

Table 4.2 Percent Maximum Heart Rate Range Required by the MMH Task in No-Belt And Belt Conditions

Participant	Age (yr)	HR_{max} (220 – Age)	No-belt condition			Belt condition			Decrease in %HR with belt
			HR_{rest}	HR_{work}	%HR capacity	HR_{rest}	HR_{work}	%HR capacity	
1	21	199	73	96.3	18.5	75	89.8	11.9	6.6
2	18	202	72	86.3	11.0	63	86.3	16.8	-5.8
3	25	195	68	115.4	37.3	61	100.0	29.1	8.2
4	20	200	68	85.8	13.5	67	82.7	11.8	1.7
5	48	172	62	77.2	13.8	64	82.2	16.9	-3.0
6	24	196	71	107.9	29.5	74	93.7	16.1	13.4
7	18	202	68	90.3	16.6	55	82.6	18.8	-2.1
8	23	197	71	110.4	31.3	73	109.7	29.6	1.7
Average					21.4			18.9	2.6
Standard deviation					9.8			6.9	6.4

4.2 Blood Pressure

The diastolic blood pressure (DBP) and systolic blood pressures (SBP) in mm Hg taken immediately after the MMH task for all participants with belt and without belt are displayed in Figure 4.2 and enumerated in Table 4.3. For most of the participants the change in DBP was not significant between the two conditions, with an exception of the participant #8. SPB was lesser in case of belt condition for six of the eight participants, with the participant #7's SBP showing considerably lesser (38 mm Hg) in case of belt condition. The overall samples means for DBP/SBP were 67/114 for no-belt condition and 64/106 for belt condition, respectively. Thus the belt condition reduced DBP and SBP by 3 and 9 mm of Hg, respectively.

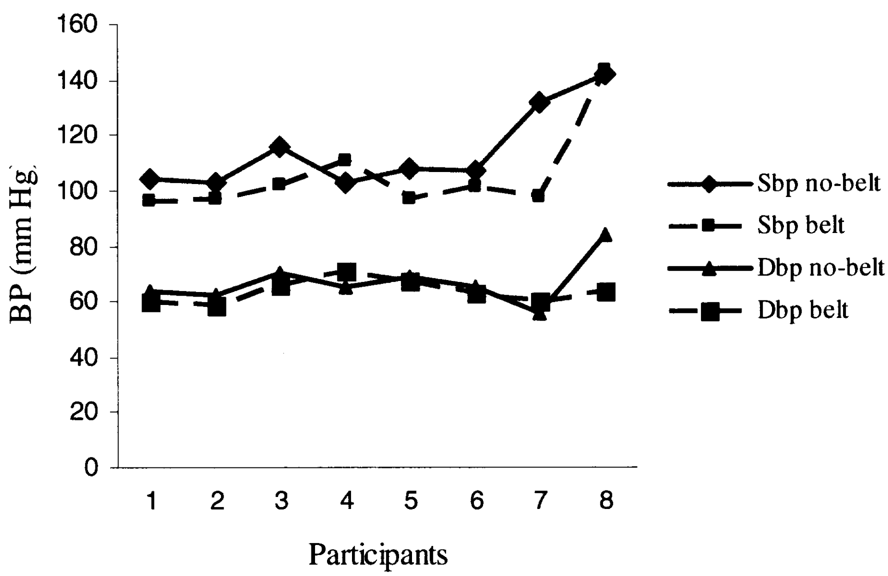


Figure 4.2 Diastolic and systolic blood pressures immediately after the exercise.

Table 4.3 Diastolic and Systolic Blood Pressures (mm Hg) Immediately After Completion of the MMH Task

Participant	Diastolic			Systolic		
	No-belt	Belt	Difference	No-belt	Belt	Difference
1	64	60	4	104	96	8
2	62	59	3	103	97	6
3	70	66	4	116	102	14
4	65	71	-6	103	111	-8
5	69	67	2	108	97	11
6	65	63	2	107	101	6
7	56	60	-4	132	98	34
8	84	64	20	142	143	-1
Average	67	64	3	114	106	9
Stdev	8.1	4.1	7.8	14.8	15.9	12.3
		t' =	1.14			2.01
		p =	0.146			0.042

A matched pair *t*-test (see Table 4.3) revealed that the reduction in DBP was not significant (p = 0.146) but the reduction in SBP was statistically significant (p = 0.042).

4.3 Static Lift Capacity

The average static lift capacity for all participants before the exercise without the back support belt was 21 kg and with the usage of the back support belt it was reduced to 17 kg. The average static lift capacity after the exercise was completed for participants without the back support belt was 20.8 kg and with the back support belt it was reduced to 17.9 kg. Based on the average lift capacities, calculated by averaging out the before and after values for each of the belt conditions (Table 4.4), the overall differences in average from no-belt to belt condition came out to be 4.1 kg.

Table 4.4 Static Lift Capacities (in kg) Before and After the MMH Task with No-Belt and Belt Conditions

Participant	No-belt condition			Belt condition			Average difference
	Before	After	Average	Before	After	Average	
1	14	15	15	11	14	12	3
2	26	16	21	10	10	10	11
3	28	29	29	27	36	32	-3
4	26	27	27	20	20	20	7
5	5	10	8	8	8	8	0
6	36	38	37	26	30	28	9
7	26	22	24	10	18	14	10
8	7	9	8	17	7	12	-4
Average	21.0	20.8	21.1	16.1	17.9	17.0	4.1
Standard deviation	11.0	10.1	10.3	7.5	10.5	8.8	6.0

This means the average lift capacity of the participant was reduced by 8.8 lbs, when they wore the back support belt. A matched pair *t*-test revealed that the p-value of the test is 0.0564 (Table 4.4), thus marginally not significant.

Research findings on back support belts support that wearing back belt induces a psychological effect on participants of being reminded to keep the proper posture and to lift more ergonomically. This reduction might be explained from the fact that back support belt might have helped them to maintain a more upright torso and reminded the participants to pull by their upper body and legs. As opposed to the above, generally without the back support belt participants might have pulled with more bent back posture, resulting in a higher maximum lift force.

4.4 Rate Body Discomfort

The discomfort ratings were on a 0-10 point scale with the highest rate of discomfort/pain being 10 and the lowest rate of discomfort/pain being 0. Combined discomfort ratings for no-belt and belt conditions, the lower back had the highest average score of 2.25, followed by the knees and upper back with score of 1.0, arms at 0.8125 and shoulders at 0.75. The average body discomfort rate for the lower back while wearing a belt was 2.4 versus no belt was 1.875. No systematic or significant changes in body discomfort pattern were observed between no belt and with belt conditions. The average body discomfort scores are displayed in Figure 4.3. The details of body discomfort rate scores for the participants are provided in Table 4.5.

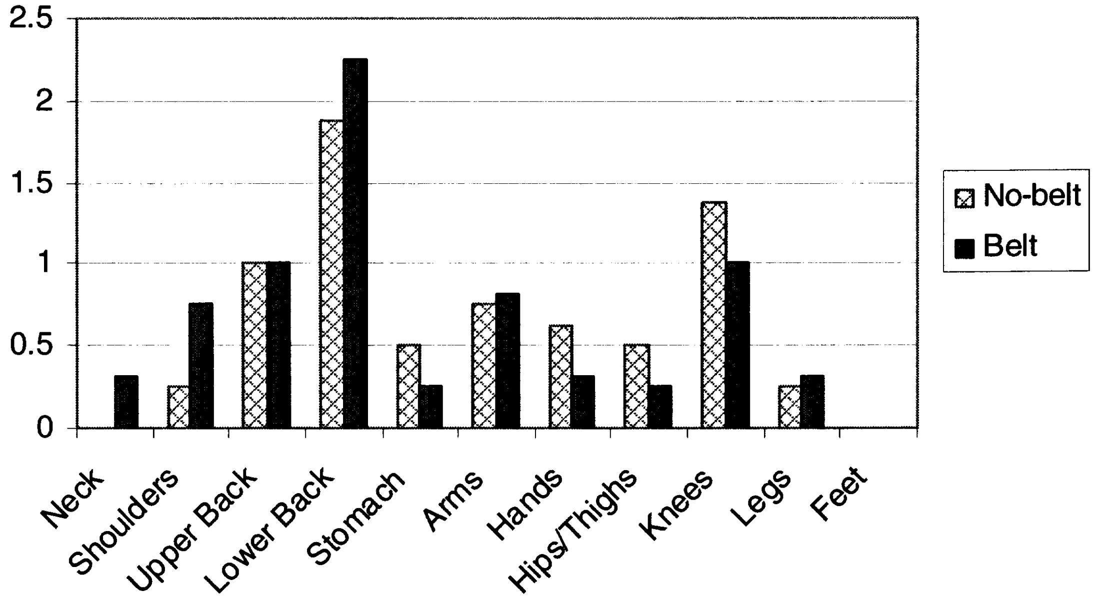


Figure 4.3 Average body discomfort scores (0-10 scale) recorded after the experimental MMH task.

4.5 Questionnaire

The questionnaire was created to assess participants' preferences towards wearing a back support belt during the exercise. The questionnaire consisted of seven questions that were all pertaining to the effectiveness of the back support belt and the positive or negative effects it may pose during the exercise. Table 4.6 displays all the questions, along with the scoring hints used and the average scores of the participants. It can be seen from Table 4.6 the average scores show a very strong positive perception of the participants towards the usefulness of back support belt.

Table 4.5 Body discomfort ratings in 0-10 scale after completion of the MMH task.

Participant	Neck	Shoulders	Upper Back	Lower Back	Stomach	Arms	Hands	Hips/Thighs	Knees	Legs	Feet
WITHOUT BELT											
1	0	0	1	5	0	0	0	0	0	0	0
2	0	0	0	5	0	0	0	0	6	0	0
3	0	0	0	0	0	0	0	0	5	0	0
4	0	0	0	0	0	0	3	0	0	0	0
5	0	0	0	5	0	0	0	0	0	0	0
6	0	0	0	0	4	4	2	4	0	2	0
7	0	0	5	0	0	0	0	0	0	0	0
8	0	2	2	0	0	2	0	0	0	0	0
Average	0	0.25	1	1.88	0.5	0.75	0.63	0.5	1.38	0.25	0
WITH BELT											
1	0	0	5	5	0	0	0	0	0	0	0
2	0	0	0	5	0	0	0	0	5	0	0
3	5	5	0	0	0	5	0	0	0	0	0
4	0	0	0	3	0	0	0	0	0	0	0
5	0	0	0	5	0	0	0	0	0	0	0
6	0	0	3	3	0	2	0	0	0	3	0
7	0	5	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0
Average	0.63	1.25	1	2.63	0	0.88	0	0	0.63	0.38	0
Overall average	0.31	0.75	1	2.3	0.3	0.81	0.31	0.25	1	0.313	0

Table 4.6 Average Scores of the Participants for the Questionnaire Eliciting Their Perception About the Back Support Belt

Number	Questions and the scoring hints used	Average Scores
1	How would you rate the help given by the belt? No help (1), Some help (3), Total support (5)	4.0
2	Did you find the belt was making you too hot or uncomfortable? Not at all (1), Some what (3), Very uncomfortable (5)	1.4
3	Did the belt cut off any blood circulation? No (1), Maybe (3), Yes (5)	1.5
4	Did you feel the test time was too long to wear the belt? Not at all (1), Indifferent (3), Yes it is (5)	1.1
5	How long do you speculate the belt would remain comfortable? Less than 1 hour(1), Several hours (3), All day (5)	3.5
6	How restrictive was the belt during the exercise? Not at all (1), Somewhat (3), Very restrictive (5)	2.1
7	If your job required extended periods of manual material handling, would you choose to wear this belt if your employer made it available to you? No (1), Maybe (3), Yes (5)	4.6

The participants strongly felt that the belt provided support (question # 1), belt was not uncomfortable (question # 2), belt did not cut any circulation (question # 3), duration of belt wearing was not excessive (question # 4), speculated that the belt can be worn at a stretch for several hours (question # 5), wearing belt posed mild restriction during task performance (question # 6), and they would choose to wear belt in work if made available (question # 7).

CHAPTER 5

CONCLUSION

This research, for the first time, investigated effectiveness of back belts on an asymmetrical MMH task performed between knuckle height and waist height. This height range permitted the participant to perform the repetitive task without any severe bending or flexion of torso, which might have produced some different physiological effects from that of the previous studies.

None of the previous studies (Marley and Duggasani 1996, Rabinowitz et al. 1998, and Bobick et al. 2001) found any significant reduction in heart rate between belt and no belt condition. As opposed to that, results of this study produced a statistically significant ($p = 0.035$) reduction in average heart rate by 5.3 bpm. Heart rate pattern during exercise showed a consistent reduction of heart rate level for 5 out of the 8 participants. In terms of percent of maximum heart rate capacity also, the average value was reduced by 2.6%, however, the reduction was not statistically significant. This reduction can only be attributed to the effectiveness of the back belt in sharing the torso supporting work by the back muscles.

Results of this study in terms of diastolic blood pressure showed no effect of back belt and agree to the conclusions derived by Rabinowitz et al. (1998) and Bobick et al. (2001). But the average systolic blood pressure showed a statistically significant ($p=0.042$) reduction of 3 mm of Hg. Reduction of systolic blood pressure shows that the heart contracted with lesser intensity and generally indicates reduction in body's internal stresses. Marley and Duggasanis' (1996) findings of increase in systolic blood pressure by 3mm of Hg; therefore, concerns of adverse health effects on workers who are hypertensive or near hypertensive have already been questioned by other researchers. Moreover, the results of this study have found no such adverse health effects of back support belts.

The static lift capacity was found to be less with the back support belt by 4.1 kg as compared to no-belt condition. This result was contrary to the increase in maximum lift capacity with back support belts found in Chen's (2003) study. This may have resulted from participants keeping the correct posture and psychologically lifting with their knees versus with their upper body.

The results for rate body discomfort and the questionnaire survey were similar to the Rabinowitz et al.'s (1998) findings. On an average the participants scored slightly higher discomfort ratings with the back support belt. Results from the questionnaire survey displayed that participants not only recommend the back support belt, but also preferred working with the back support during the experiment. Rabinowitz et al.'s (1998) survey resulted in all 10 subjects perceiving the safest lifting method to involve the use of the belt, 50% rated the belt as their least preferred lifting condition.

Throughout this study, I have discovered that a female perception on what they can lift (psychophysical factors) is greatly influenced by the usage of a back support belt. Most female subjects were surprised to find that lifting with a back belt would make a difference for the experiment. The participants had a positive perception about the protective effect of the back support belt and would recommend the usage of such help in asymmetric repetitive lifting. Moreover, the physiological results of this study did prove the idea of reduction of physiological stress in asymmetric repetitive lifting via lower heart rate and blood pressure with back belt versus no back belt.

In conclusion, the results of this study suggest that industrial back belts may reduce internal stresses during asymmetric manual material handling tasks performed within kneed and waist level. At this point, more research is needed and it is yet to be determined whether back belts will significantly reduce internal stresses during asymmetric repetitive lifting, which does not involve severe bending below waist level. Studies should investigate the effect for manual material handling in other planes such as, between waist to shoulder level, and knuckle and shoulder levels, possibly by increasing sample size and handling larger weights. Future studies can experiment with male subjects who may lift a higher maximum allowable weight on average and depict more significant physiological results.

APPENDIX A

INFORMED CONSENT FORM

NEW JERSEY INSTITUTE OF TECHNOLOGY
323 MARTIN LUTHER KING BLVD.
NEWARK, NJ 07102

CONSENT TO PARTICIPATE IN A RESEARCH STUDY

TITLE OF STUDY: DETERMINATION OF THE EFFECTS OF THE INDUSTRIAL BACK SUPPORT BELT ON THE MANUAL MATERIAL HANDLING CAPACITY OF FEMALE MATERIAL HANDLERS

RESEARCH STUDY:

I, ______________________________________, have been asked to participate in a research study under the direction of Dr. Arijit K Sengupta, Associate Professor, Department of Engineering Technology, NJIT.
Other professional persons who work with them as study staff may assist to act for them.

PURPOSE:

To investigate whether (1) use of an industrial back support belt has any effect on my voluntary material handling capacity and (2) the psychophysical effects from lifting belts will create a false sense of security.

DURATION:

My participation in this study will last for approximately 2 hours for one to two days.

PROCEDURES:

I have been told that, during the course of this study, the following will occur:

As a volunteer in this project I will be given a standardized instruction and training on how to lift the box from a table and transfer the box to a platform kept at my approximate knee height. During the experimental session, the weight of the box will be adjusted based on my assessment on the maximum weight that I feel comfortable to handle for such a task. The weight of the box in no case will be allowed to exceed 30 lbs.

After I set my acceptable weight limit for the task by trial and error method, I will be performing approximately 60 such transfers per experimental session for approximately

20 minutes. There will be two such sessions, one with wearing a standard industrial back support belt and another session without the belt. During either of these sessions, I will have the complete liberty to discontinue the handling task if I feel uncomfortable or overstressed in any way.
Prior to the experimental session, I will required to wear a heart rate watch to collect data that will help explain the physiological effects of the working muscles during the performance of the transfer task. Additionally, my height, weight and age will also be recorded.

The experimental setup will include a table with a normal height approximately 35 inches from the floor, a platform set at approximately 20 inches from the floor and located at a horizontal distance of 36 inch from the table. The size of the box is approximately 12x12x12 inch with cut out handles, and the weight will be varied by adding or subtracting small sand filled sacks, whereas the weight of will be unknown to me.

At the end of each lifting session I will be completing a questionnaire to indicate my perceived body discomfort levels at the different joints of my body. After the completion of both the sessions, I will also be asked to rate my preferences on the performance of the back support belt using another set of questionnaire.

PARTICIPANTS:

I will be one of about ____10____participants to participate in this trial.

EXCLUSIONS:

If I have any of the following conditions I should not participate in the experimental trials:
(i) current episode or history of musculoskeletal disorders such as any joint pains or back pain, (ii) any known respiratory or cardiovascular medical conditions, such as blood pressure or history of heart attack or stroke, and (iii) pregnancy.

RISK/DISCOMFORTS:

I have been told that the study described above may involve the following risks and/or discomforts:

Discomfort to the lower back, shoulders, and legs during the box transfer trials.

There also may be risks and discomforts that are not yet known.

I fully recognize that there are risks that I may be exposed to by volunteering in this study which are inherent in participating in any study; I understand that I am not covered by NJIT's insurance policy for any injury or loss I might sustain in the course of participating in the study.

CONFIDENTIALITY:

Every effort will be made to maintain the confidentiality of my study records. Officials of NJIT will be allowed to inspect sections of my research records related to this study. If the findings from the study are published, I will not be identified by name. My identity will remain confidential unless disclosure is required by law.

PAYMENT FOR PARTICIPATION:

I have been told that I will receive $ 10 dollars per hour for duration of 2 -4 hrs for compensation for my participation in this study.

RIGHT TO REFUSE OR WITHDRAW:

I understand that my participation is voluntary and I may refuse to participate, or may discontinue my participation at any time with no adverse consequence. I also understand that the investigator has the right to withdraw me from the study at any time.

INDIVIDUAL TO CONTACT:

If I have any questions about my treatment or research procedures that I discuss them with the principal investigator. If I have any addition questions about my rights as a research subject, I may contact:

Dawn Hall Apgar, PhD Chair, IRB (973) 642-7616

SIGNATURE OF PARTICIPANT

I have read this entire form, or it has been read to me, and I understand it completely. All of my questions regarding this form or this study have been answered to my complete satisfaction. I agree to participate in this research study.

Subject Name:____________________
Signature:__________________________

Date:__________

SIGNATURE OF READER/TRANSLATOR IF THE PARTICIPANT DOES NOT READ ENGLISH WELL

The person who has signed above, ______________________________________, does not read English well, I read English well and am fluent in (name of the language) ______________________________________, a language the subject understands well. I have translated for the subject the entire content of this form. To the best of my knowledge, the participant understands the content of this form and has had an opportunity to ask questions regarding the consent form and the study, and these questions have been answered to the complete satisfaction of the participant (his/her parent/legal guardian).

Reader/Translator Name:____
Signature:____
Date:__________________

SIGNATURE OF INVESTIGATOR OR RESPONSIBLE INDIVIDUAL

To the best of my knowledge, the participant, ______________________________, has understood the entire content of the above consent form, and comprehends the study. The participants and those of his/her parent/legal guardian have been accurately answered to his/her/their complete satisfaction.

Investigator's Name:____________________
Signature:_______________________

Date:______________

APPENDIX B

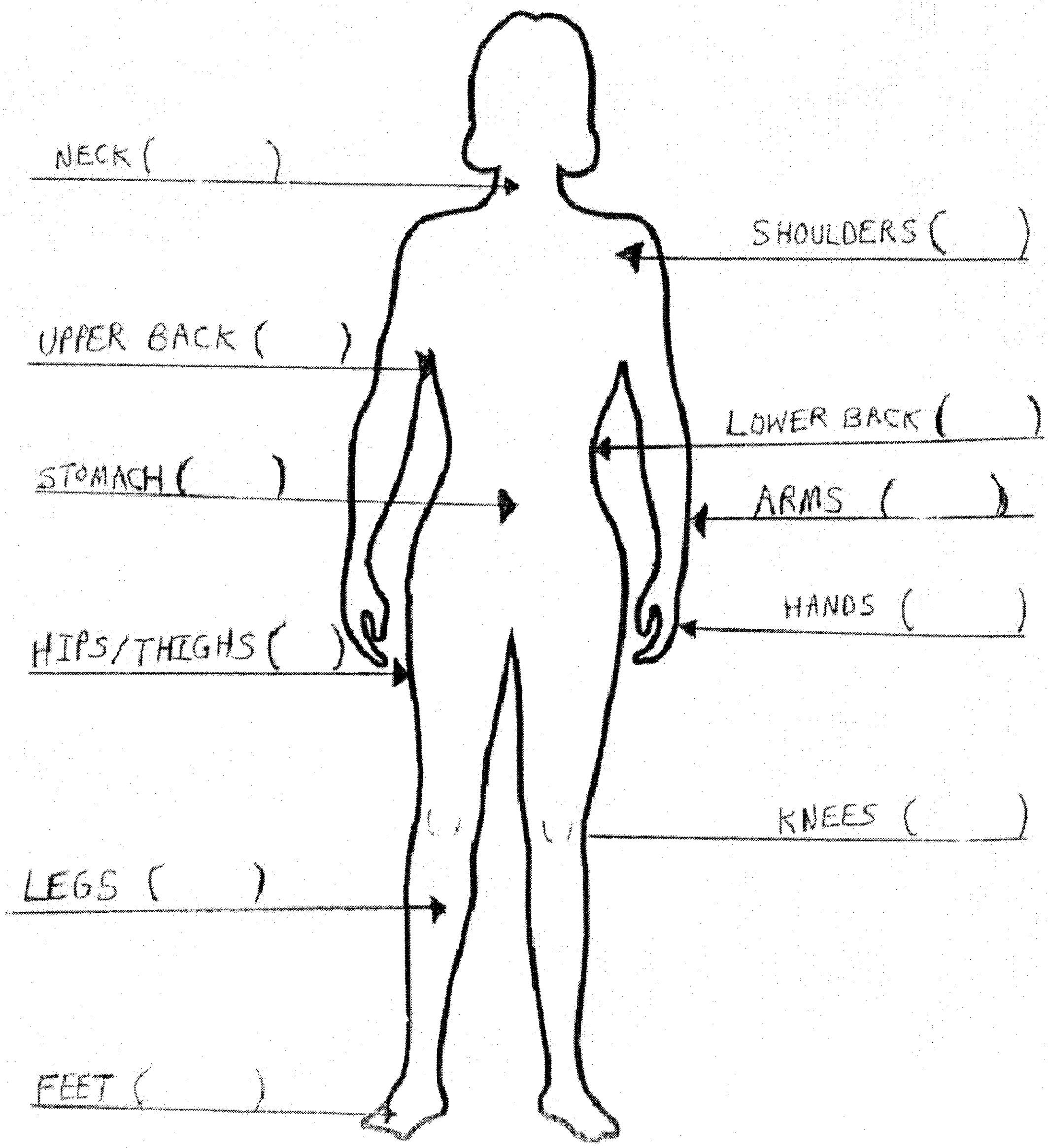
RATE OF BODY DISCOMFORT DIAGRAM

Rate Body Discomfort/Pain
(0 to 10)

0 – No Pain/Discomfort

5 – Moderate Pain/Discomfort

10 – High Pain or Discomfort



APPENDIX C

QUESTIONNAIRE

Questionnaire to assess the use of back support belts

(1) How would you rate the help given by the belt?

1 -------------------- 2 -------------------- 3 --------------------- 4 --------------------- 5
No help Some help Total support

(2) Did you find the belt was making you too hot or uncomfortable?

1 -------------------- 2 -------------------- 3 --------------------- 4 --------------------- 5
Not at all Some what Very uncomfortable

(3) Did the belt cut off any blood circulation?

1 -------------------- 2 -------------------- 3 --------------------- 4 --------------------- 5
No Maybe Yes

(4) Did you feel the test time was too long to wear the belt?

1 -------------------- 2 -------------------- 3 --------------------- 4 --------------------- 5
Not at all Indifferent Yes it is

(5) How long do you speculate the belt would remain comfortable?

1 -------------------- 2 -------------------- 3 --------------------- 4 --------------------- 5
Less than 1 hour Several hours All day

(6) How restrictive was the belt during the exercise?

1 -------------------- 2 -------------------- 3 --------------------- 4 --------------------- 5
Not at all Somewhat Very restrictive

(7) If your job required extended periods of manual material handling, would you choose to wear this belt if your employer made it available to you?

1 -------------------- 2 -------------------- 3 --------------------- 4 --------------------- 5
No Maybe Yes

APPENDIX D

DATA COLLECTION FORM

PRIVATE & CONFIDENTIAL
Participant Number:

Contact information	Demographic data
Name	Height:
Address	Weight:
	Occupation:
Telephone number	Material handling experience:
Email address (optional)	Remark:

NO BELT					
Date and Time					
Resting Heart Rate					
Resting Blood Pressure					
Static Load Capacity (lbs)					
MAWL Starting Load (lbs)					
MAWL Maximum Load (lbs)					
Heart rate (every min.)					
Average Heart Rate					
Blood Pressure at the end of exercise					
Final Static Load Capacity (lbs)					

WITH BELT					
Date and Time					
Resting Heart Rate					
Resting Blood Pressure					
Static Load Capacity (lbs)					
MAWL Starting Load (lbs)					
MAWL Maximum Load (lbs)					
Heart rate (every min.)					
Average Heart Rate					
Blood Pressure at the end of exercise					
Final Static Load Capacity (lbs)					

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