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Occupational Risk Factors and Back Injury

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Twenty-one risk factors affecting laborers in manual materials handling tasks were analyzed to determine what, if any, statistically significant relationships existed between the factors and the emergence of occupational back injury. The statistically significant risk factors ($p \leq .05$) *in the univariate analysis were determined to be weight lifted per hour (work intensity), trunk twists per hour, weight lifted per day, frequency of lift, trunk motions per hour, and trunk flexions per hour, with odds ratios (*OR*s) of 1.28–2.88. In addition, self-reported discomfort in the neck, middle back, knees, and lower back was associated with the outcome of back injury* ($p \leq .05$, OR *1.75–2.66). In the multivariate analysis, the statistically significant risk factors* ($p \leq .05$) *were weight lifted per hour (work intensity), average weight of lift, and number of trunk twists per hour, with* OR*s of 1.74–4.98.*

occupational risk factors   manual materials handling   occupationally-related back injury

1. INTRODUCTION

Compensation claims and lost workdays due to low back pain are some of the largest financial strains on industry [1]. It has been estimated that over 20% of all private sector injuries involve the back, and these claims make up a large percentage of what is paid out by workers' compensation companies [1]. In 2009, sprains and strains accounted for 40% of injuries and illnesses resulting in days away from work and most often involved the back [2].

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Forty percent of all absences from work result from leave due to back pain [3]. Studies show that half of all workers who leave work for low back pain are on leave for over 6 months and three quarters of people who were out for a year never recover to resume their previous positions [4].

With all of the issues associated with the human back, science seeks to find solutions to problems associated with the low back and predictors for preventing those problems. Despite this clear goal, the task set before the medical and engineering fields is not an easy one.

The human back is an intricate system of muscles, bones and intervertebral discs, nerves, and tendons [5]. It is such a unique system that it has proved to be an enormously challenging task for ergonomics professionals, physicians, and other researchers to develop an accurate model for use in predicting low back injuries.

Due to the numerous challenges of modeling the back as a mechanism, it may prove prudent to study jobs and current injury rates to find what parts of those jobs make them particularly susceptible to injuring the worker. To do this, one must analyze the job and dissect it to determine specific risk factors. Potential risk factors are likely to come from four main categories: epidemiological, biomechanical, physiological, and psychophysical [6]. An occupationally functional method to analyze the risk factor groups is to categorize them as personal, occupational, nonoccupational, and psychosocial [7]. Instead of isolating one risk factor, this study will attempt to correlate several factors in an attempt to discover how their interaction may be associated with back injury.

This research reviewed 21 occupationally-related risk factors frequently found in manual materials handling industries. The data were taken from nine locations across the USA and included workers in 15 different job positions.

2. RISK FACTORS

2.1. Frequency of Lift/Lower

As a worker performs a task faster, their chance for an injury may increase. This premise has been the inspiration for previous research topics [8, 9]. The frequency of a task has been incorporated in many of the current tools available for the analysis of manual handling tasks, including the revised NIOSH lifting equation [10]. It has been found that as the frequency of the loading rate is increased, the stress on the spine increases [8]. In addition, higher frequency tasks may increase energy expenditure to higher than desired rates, potentially increasing the chance for injury [9, 11].

2.2. Average and Maximal Weight of Lift

Perhaps one of the more obvious risk factors to consider is the weight of the lift. The force on the trunk changes with both the magnitude and force of the load [12]. As the weight of lift increases, so does the moment exerted on the spine and this maximal load moment has been identified as an indicator of risk in low back disorders [13]. Some studies have made an attempt at quantifying the maximum weight of lift as a function of some other variable [6]. Such approaches include, but are not limited to, epidemiological factors, biomechanical factors, and psychophysics.

2.3. Pounds Lifted/Lowered Per Day/Hour

Frequent repetitive lifts can be shown to induce fatigue, which may be a prime cause of injury [12]. As previously discussed, the weight of lift and frequency may be a leading cause of injury to the back. Combining these two risk factors, an average weight of lift per unit time is devised. The pounds lifted/lowered per unit of time for a heavy load at a low frequency may have similar risk as a light load with a high frequency, but it is useful to note that these two indices may have different effects on the muscles in the back [12].

2.4. Bending, Twisting, and Static Postures

Posture has an effect on the use of back muscles, and some postures may isolate certain muscle groups; this muscle group isolation may increase the probability of injury in the back [14]. Additionally, isolating certain muscle groups changes medial power frequency patterns, which is shown to increase fatigue in manual material handling tasks [12].

2.5. Estimation of Energy Expenditure

Energy expenditure can be estimated by measuring heart rate and oxygen consumption [7]. Establishing the heart rate/oxygen consumption relationship for each worker individually with ergometric testing allows researchers to estimate at what level of oxygen consumption each worker is working, based on their measured heart rate [15]. These two physiological responses to work are measured directly with a heart rate monitor and a portable oxygen consumption measuring device (Oxylog; Morgan Scientific, USA). After some level of energy expenditure, based on individual physiological conditioning and motivation, the body begins to display signs of fatigue. Fatigue causes motor control to lessen, which increases neuromuscular inefficiencies, which is believed to be related to injury [16].

2.6. Body Part Discomfort Survey

The body part discomfort survey is a technique used by ergonomics professionals in an attempt to relate subjective body-part discomfort with different jobs or tasks. One of the common types of these surveys is a map of the human body and a scale that participants use to relate what level of discomfort, if any they are experiencing [17].

2.7. Perceived Effort

Perceived exertion is necessary to accurately describe back injury risk factors, due to the sometimes-ambiguous results found associating results found in associating physical factors [18]. The Borg rating of perceived exertion scale is used to estimate the perceived effort of a person [19]. Ergonomics professionals use the Borg scale to evaluate the perceived intensity of physical exertion [20].

2.8. Length of Time Employed

Cumulative trauma disorders, repetitive strain injuries, and musculoskeletal disorders are all terms to describe the phenomenon that exists when repetitive jobs produce discomfort in the body [21]. Some studies have shown that in tasks where the handler must carry large amounts of product, the likelihood of back injury over time increases [22]. However, the relevance of the studies themselves may not be very high, due to errors inherent in current techniques [23].

3. METHODS

3.1. Participants

Volunteers for this study were selected from three large U.S. companies spread among nine locations. There were 403 men and 39 women included. Eligible participants had at least 6 months of experience, to negate any potential learning curve and work hardening effects. Eighty-three percent of the eligible population agreed to and participated in the research.

3.2. Procedure

Participants from each job were subjected to a rigorous battery of tests, which covered several factors that are hypothesized to have an effect on the lower back. Data on the following factors were collected: lifting/lowering frequency, percentage of time performing manual materials handling tasks, size and weight of materials, workspace, origins and destinations of transfers, carrying activities, body motions, working postures, working heart rate, working $\dot{V}_{O2}$, and percentage of workers' $\dot{V}_{O2max}$ over the duration of the job. Using SPSS version 11.0, univariate and multivariate logistic regression was performed to determine potential correlations between these factors and back injury. All participants first completed an informed consent form, then were issued a Polar Vantage XL heart rate monitor (Polar Electro, Finland) each, and then went about their normal jobs without disruption. The complete original testing protocol was approved by the Institutional Review Board for Use of Human Subjects at Texas A&M University, College Station, USA.

3.3. Data Acquisition

To minimize the interference of the observer on the worker, videotape was used to gather the required job-related information. Analysis of videotape made it possible to document biomechanical stressors, gross motions by the participant, frequencies of movement, task durations, and job activities. The guidelines Grant suggested were followed [24]. Using interparticipant and intraparticipant videotape analysis, material handling frequencies and participant postures were gathered.

The data on material weights and dimensions were obtained via either direct measurements or by way of company records received from the companies involved. Types of materials being handled and detailed statistical descriptions of the weights, including average material weight and weight distributions, were provided by each company to the researchers. The researchers directly measured other necessary materials data that were not readily available from the companies to obtain an average weight and distributions of that weight. Workplace layout was determined by either company-supplied blueprints or by direct measurements.

3.4. Handling of Materials

Videotape analysis provided the data for frequency of lift calculations. Average weight of lift was obtained from either company records or direct measurements. Data for weight of lift per day and weight of lift per hour were collected by combining videotape analysis techniques, company records review, and direct measurements.

3.5. Body Motions and Postures

Videotape analysis was used to determine static postures, trunk flexion ≥45°, trunk twisting ≥45°, knee flexion ≥45°, shoulder flexion ≥45°, shoulder flexion ≥90°, and shoulder abduction ≥45°. These postures related object load with respect to the participant's body for both the origin and destination.

Trunk motions were calculated by adding the number of trunk motions ≥45° to the number of trunk twists ≥45°. Video analysis also made it possible to measure static trunk flexion ≥45° and static shoulder flexion ≥90°.

3.6. Physiological Response

Working heart rate, estimated working $\dot{V}_{O2}$ consumption, and working percentage of $\dot{V}_{O2\max}$ were measured during the workers' normal work shifts. The Polar Vantage XL heart rate monitor was used to obtain working heart rates. Heart rates were recorded with the watch monitor and downloaded to the computer for analysis.

To determine each participant's heart rate oxygen consumption relationship, the participant's $\dot{V}_{O2\max}$ had to be estimated first. Conducting a submaximal step test on each participant gave the research this value. Craig, Congleton, Kerk, et al. [11] and Bales, Craig, Congleton, et al. [25] reviewed the validity of using ergometric tests. From this value and the gathered average working heart rate, the working $\dot{V}_{O2}$ consumption for each participant was estimated by interpolation.

The percentage of maximal $\dot{V}_{O2}$ was calculated for all participants over their respective shifts. These calculations were compared to the recommended values from literature. It is recommended that the working level of $\dot{V}_{O2}$ consumption for any person should not exceed 33% of that person's maximum for shifts that last 2–8 h [26].

3.7. Subjective Ratings and Length of Time Employed

To quantify the overall health of each participant, a body part discomfort survey and a perceived exertion survey were requested from each participant [27]. Additionally, all participants were asked about the length of time employed at their current employers, if they currently had another job, and the length of time spent in their position.

3.8. Injury/Illness

Injury and illness data were obtained from company safety records. Each participant was monitored for a period of 1 year after the initial testing protocol, or for the remaining term of employment. Recordable back injuries caused by a worker activity were included in the collection. Of the total population, 31.1% experienced some sort of work-related injury or illness during that 1-year period.

3.9. Data Analysis

Analysis using both descriptive and inferential statistics was performed with SPSS version 11.0 and Microsoft Excel. Univariate logistic regression was performed on the data to determine the correlation of each risk factor and the likelihood of injury or illness. Significant variables from the univariate model were then entered into a multivariate model to determine correlations between factors using forward selection and backward elimination.

4. RESULTS

4.1. Descriptive Statistics

Twenty-one variables were identified and collected as potential factors affecting the risk of back injury to workers. Each variable gathered from this study was entered into the SPSS software individually in a univariate logistical regression analysis. Additionally, the variables were divided further, to compare the results to job classification. Sections 4.1.1.–4.1.10. summarize the statistical output.

4.1.1. Frequency of lift

A high frequency of lift was common among most participants in the study. Repeated sampling techniques were used to produce an average rate of lift for each job classification. Each job classification had different lift frequencies, and the average rate of lift was assigned to each classification. The average lifting frequency for the population was 834.9 lifts per hour (σ 433.2, *Mdn* 577.0, skewness 0.15).

4.1.2. Average weight of lift

Average weight of lift data were collected each of the participants. The average weight of lift for these participants was 7.2 kg (15.8 lb) (σ 4.1 kg [9.0 lb], *Mdn* 5.6 kg [12.3 lb], skewness 2.92). The minimum average lift encountered was 1.8 kg (3.9 lb) and the maximal average lift encountered was 22.6 (49.8 lb). Most participants (88.8%) were found to have average weights of lift between 3.7 kg (8.2 lb) and 7.8 kg (17.2 lb). Each job classification had a different average weight of lift, and each classification was assigned the average weight observed in the analysis. The materials handled had a normal distribution of weight about their individual mean weights.

4.1.3. Pounds lifted per hour (work intensity)

Since the 15 different job classifications had varying shift durations, the researchers developed a leveling factor referred to as work intensity rather than merely averaging the total pounds lifted per day for each job classification. The work intensity was defined to be total weight lifted per hour. The average work intensity for the population studied was 5057 kg (11 126 lb) per hour (σ 2193 kg [4825 lb], *Mdn* 4511.4 kg [9924.5 lb], skewness –0.08).

4.1.4. Maximal occupational weight of lift

The average maximal weight of lift for all participants was 41.9 kg (92.1 lb) (σ 10.9 kg [24.0 lb], *Mdn* 50.0 kg [110.0 lb], skewness –1.02). The range of maximal lifts was observed to be 13.6 kg (30 lb) to 50 kg (110 lb). Sixty-one percent of the workers lifted weights of 45 kg (100 lb) or higher in a typical day.

4.1.5. Body motions

Body motions observed and measured include trunk flexions and twists, static trunk flexions, knee flexions, shoulder flexions, static shoulder flexions, and shoulder abductions. These motions were observed, and either the number of occurrences or the length of time was recorded, depending on the factor.

The number of trunk flexions per worker of ≥45° recorded in a day ranged from 35 to 454. The average number of observed trunk flexions was 302.8 (σ 107.8, *Mdn* 318.0, skewness –0.86). The number of trunk twists per day averaged 100.2 (σ 57.6) and ranged from 5 to 233 (*Mdn* 65.0, skewness 0.30). The addition of trunk flexions and trunk twists yields another category; trunk motions. The number of trunk motions was observed to range from 40 to 616, with a mean of

403.0 (σ 154.4, *Mdn* 383.0, skewness –0.56). Although the number of trunk motions varied from one job description to the next, over three quarters of the participants performed at least 380 trunk motions per hour. Time spent in trunk flexion was also recorded. These data yielded that the average amount of time that a worker spent in static trunk flexion in a given workday was 8.6 min (σ 4.2) (*Mdn* 11.0, skewness –0.12).

Knee flexions of ≥45° were recorded and averaged 92.6 (σ 60.9); they ranged from 0 to 187 (*Mdn* 71.0, skewness 0.45). In addition to trunk motions and knee motions, data on shoulder motions were collected. The average number of shoulder flexions between 45° and 90° per hour was 118.9 (σ 79.8, *Mdn* 150.0, skewness –0.10). The number of shoulder flexions ≥90° per hour had a mean of 128.3 (σ 85.4, *Mdn* 80.0, skewness 0.49). Time spent in static shoulder posture ≥90° per hour in a workday averaged 3.09 min (σ 1.93, *Mdn* 2.0, skewness 0.36). Lastly, the number of shoulder abductions per hour was found to average 91.4 (σ 66.9, *Mdn* 75.0, skewness 0.63).

4.1.6. Average working heart rate and average working oxygen consumption

The average working heart rate for the participants in the survey was 115.7 (σ 15.1, *Mdn* 114.0, skewness 0.28). The average working oxygen uptake experienced by the population during their shifts was found to have a mean of 1.4 L/min (σ 0.4, *Mdn* 1.4, skewness –0.07).

4.1.7. Percentage of maximal aerobic power and percentage of maximal aerobic power above the recommended 33%

The ratio of the average working heart rate to the maximum recommended heart rate was calculated to be a mean of 47.8% (σ 13.4, *Mdn* 47.5%, skewness –1.79) of the population studied. Most participants were working above the recommended aerobic power limit; 85.8% of the surveyed workers had a working $\dot{V}_{O2}$ consumption of over 33% of their maximum.

4.1.8. Body part discomfort

The results of a body part discomfort survey gave statistics describing discomfort for 17 body parts. The back had the highest average discomfort from among the body parts, with the low back receiving an average rating of 25.8 and the middle back receiving an average rating of 10.8 (scale 0–100). Other averages were shoulders (σ 9.5), wrists (σ 9.1), knees (σ 8.1), and feet (σ 6.3). The discomfort values ranged from 0 to 100.

4.1.9. Borg scale rating

The mean perceived exertion as per the Borg perceived exertion scale was 15.4 (σ 2.4). According to Borg, this result is classified as *hard* (27). Further analysis revealed that most participants perceived their job as being *somewhat hard*, *hard*, *very hard*, or *very, very hard*.

4.1.10. Length of time employed

These companies have fairly high turnover rates, as is indicated by the length of time employed. The mean time employed at the company at which each participant was currently employed was 3.1 years (σ 3.9). Over 70% of the workers in this survey had been with their current employer for 2.5 years or less.

4.2. Inferential Statistics

Logistic regression was used to determine which of the factors were significant with respect to the existence of low back injury. Each of the 21 occupational risk factors was individually entered into a univariate analysis. Those occupational variables that satisfied the minimal inclusion criteria ($p \le .10$) were entered into the multivariate analysis. In addition, each body part covered by the body part discomfort survey was entered into the univariate analysis. If the minimal inclusion criteria were met by this data, that factor was also considered in the multivariate analysis.

4.2.1. Univariate analysis

All 21 of the variables were analyzed to determine the correlation with back injury. Nine variables met the criteria for inclusion ($p \leq .10$) in the multivariate analysis. Work intensity, trunk twists per hour, weight lifted per day, frequency of lift, trunk motions per hour, trunk flexions per hour, knee flexions per hour, time in static trunk flexion, and average weight of lift were all selected for inclusion in the multivariate analysis. Additionally, six of these nine variables were found to be significant through the univariate analysis ($p \leq .05$). Table 1 summarizes the results of the univariate analysis.

Five of the 17 body parts identified in the body part discomfort survey met inclusion criteria for the multivariate analysis. The neck, middle back, lower back, knees, and ankles all had $p < .10$. Table 2 indicates all of these body parts were considered significant ($p \leq .05$) with the exception of the ankles.

4.2.2. Multivariate analysis

A multivariate analysis was conducted on the nine occupational risk factors and five body parts that met the inclusion criteria of $p \leq .10$. Of these 14 factors, 3 significantly influenced the occasion of injury to the back. Table 3 summarizes these results.

5. DISCUSSION

This study analyzed the association between 21 occupational risk factors and the subsequent emergence of injury to the back. Of the potential population for inclusion as participants in this study, 83% participated. A substantial majority of these participants had jobs that required them to lift a large amount of weight in a day, averaging

TABLE 1. Univariate Analysis Results—Covariates Included in the Multivariate Analysis

Variable	*p*	*OR*	95% CI
Weight lifted per hour (work intensity)	.001	2.88	[1.55, 5.34]
No. of trunk twists per hour	.001	2.23	[1.36, 3.66]
Weight lifted per day	.002	1.28	[1.10, 1.50]
Frequency of lift	.006	2.54	[1.31, 4.91]
No. of trunk motions per hour	.006	1.34	[1.09, 1.65]
No. of trunk flexions per hour	.029	1.40	[1.04, 1.90]
No. of knee flexions per hour	.052	*ns*	*ns*
Time spent in static trunk flexion (min/h)	.061	*ns*	*ns*
Average weight of lift	.073	*ns*	*ns*

Notes. OR = odds ratio, CI = confidence interval.

TABLE 2. Univariate Analysis of Body Part Discomfort Data

Variable	*p*	*OR*	95% CI
Neck	.013	2.66	[1.23, 5.77]
Middle back	.015	2.21	[1.17, 4.19]
Knees	.031	2.19	[1.08, 4.44]
Lower back	.042	1.75	[1.02, 3.09]
Ankles	.098	*ns*	*ns*

Notes. OR = odds ratio, CI = confidence interval.

TABLE 3. Multivariate Analysis

Variable	*p*	Level	*OR*	95% CI
Weight lifted per hour (work intensity)	<.001	continuous	4.98	[2.29, 0.81]
Average weight of lift	.001	continuous	1.74	[1.24, 2.43]
No. of trunk twists per hour	.001	continuous	2.22	[1.26, 3.75]

Notes. OR = odds ratio, CI = confidence interval.

20 698 kg (45 536 lb) per day, with the most demanding jobs requiring lifting 42 614 kg (93 751 lb) per day. While the amount of weight lifted per day was significant in the univariate analysis, it was not found to be a governing factor in the multivariate analysis. Work intensity, however, demonstrated a significant multivariate association with the outcome of injury in the current population. The association between the weight lifted in a given period and lifting tasks has been studied in the past. It was for this reason that the task conditions, load weight, lifting frequency, and lifting duration, were included in the revised NIOSH lifting equation [10]. A somewhat more recent study that sought to develop an equation to evaluate manual material handling tasks included many of the same factors addressed in the revised NIOSH lifting equation [27]. This reinforces the conclusion found by this study that work intensity (weight lifted per hour) is a significant indicator of back injury.

Repetitive lifts over a given time can contribute to worker fatigue. Fatigue either is directly associated with injury or results in errors, which are directly associated to back injury [16]. A number of studies have investigated the correlation between fatigue and back injury. Such was the finding of a review of published literature by Kumar and Mital [6]. Also stated is the relationship between peak loads on the spine and the likelihood of injury.

The average weight of lift was determined to be a significant factor in the multivariate analysis of the risk factors. In this study, the average weight of lift for all jobs surveyed was found to be 7.2 kg (15.8 lb) and ranged from 1.8 kg (3.9 lb) to 22.6 kg (49.8 lb). Other studies have found similar results reinforcing the results that average weight of lift risk is a factor. Marras, Allread, Burr, et al. established that ergonomic interventions that were designed to reduce the force required of the worker to lift or move an object reduced the presence of low back disorders [28].

The number of trunk twists per hour was another significant factor in the multivariate analysis of the risk factors studied. All of the trunk motions studies were significant in the univariate model. Marras, Lavender, Leurgans, et al. found similar results [13]. The spinal movements studied there were so correlated that even the factors that were retrospectively identified were sufficiently represented in the other documented factors.

While it was found that work intensity, average weight of lift, and the number of trunk twists per hour most likely had a direct effect on the likelihood of injury to the lower back, other studies found seemingly conflicting results. In Magnusson, Gravanqvist, Jonson, et al., the maximal weight of lift, repetition, and heavy periods of lifting were not directly related to the existence of back pain [29]. An analysis of the jobs studied may explain these seemingly conflicting results. In Magnusson et al., the workers were on an assembly line and had to wait until the next engine was passed down the line. This inherently involved random periods of rest and conflicts with the constant presence of materials for the worker in this study. Also, Magnusson et al.'s study was concerned with the presence of back pain. In contrast, this study used an OSHA recordable injury to the back as the outcome variable.

Trunk twists have been studied in more detail as well. A study by Kumar, Narayan, Stein, et al. stated that trunk rotations were a factor in 60% of all back injuries [30]. Their conclusion was that twisting caused fatigue, which led to a decline in the torque capability level. This fatigue was also found to be nonuniform indicating that uneven loading on back muscles may lead to increased propensity for injury.

6. CONCLUSION

The results of this study show that injury to the low back is related to the significant risk factors discussed in the univariate and multivariate analyses. Additionally, the correlation shown by the multivariate analysis between the three factors in Table 3 suggests that the combined effects of those factors are also a major influence on the occurrence of debilitating back injury. It is important for the reader to remember the results in this research should be considered in light of the industry and population studied.

The data from both the univariate and multivariate models suggest that those factors may have a significant impact on whether or not a worker in a manual materials handling facility will develop an injury to their back. Each of these factors has a part in injury to the back and should be seriously considered in work design measures. These risk factors should be reduced or removed to reduce the risk of injury to workers.

A number of other factors could be relevant to occurrence of injury to an individual worker. Lifestyle issues, including athletic activities and fitness training could have a part in preventing injury. Attitude is an often-overlooked cause of errors, and so increasing job satisfaction should be a goal of employers concerned with the safety of their workers' backs.

Unfortunately, many companies do not go far enough in their efforts to protect the worker's back. Beyond the safety measures the government requires, few employers take added precautions to protect against back injury. Basic safety and ergonomics videos and routine safety meetings help, but a more comprehensive approach may prove to be beneficial. Companies should identify risk factors in their jobs and take measures to reduce the impact of those risks, or eliminate them altogether.

Cost to implement such programs is a common justification for not taking extra steps in the prevention of back injury. Annual reporting on the various injuries and illnesses suffered by workers in the private sector by USA's Bureau of Labor Statistics and National Safety Council provide insight on the magnitude and cost of such injuries and illnesses. In 2009, 1 158 870 injuries to full-time workers in private industry resulting in lost workdays, 236 410 were injuries to the back with 140 330 related to overexertion while lifting [1]. The sheer number of injuries to the lower back (as well as other injuries and illnesses) and their associated costs should provide sufficient data for a cost/benefit analysis to encourage the implementation of comprehensive injury and illness reduction systems.

7. FUTURE RESEARCH RECOMMENDATIONS

The participants of this research were a somewhat limiting factor on the applicability of the conclusions to industry. Demographically, most participants were young males. Inclusion of other populations, with more women and workers of different age groups, would increase the probability that the conclusions reached about the correlation of the risk factors here and injury to the back are reliable and accurate.

The industries analyzed in this study were narrowly scoped. All jobs in the population could be easily grouped in terms of light, medium, or heavy work demands. Future research should extend this type research to other industries. By doing so, other risk factors faced by manual material handlers and other jobs may be exposed, thus adding to the overall understanding of the subject. Through future research, it will eventually be possible to develop an accurate set of risk factors for the back, which will allow safety and ergonomics programs to effectively reduce the probability of injury to workers.

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