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A study of the effects of isokinetic pre-employment physical capability screening in the reduction of musculoskeletal disorders in a labor intensive work environment

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Abstract. *Objectives:* This study investigated the effects of pre-employment physical ability screening using isokinetic dynamometry in injury development, specific to musculoskeletal disorders (MSDs) of the knees, shoulders and back among workers in physically demanding jobs.
Methods: New hires ($n = 503$) from a large US employer's 105 industrial yards were screened to match the physical demands of their prospective jobs and tracked for up to 33 months. Results were compared to a control group of 1423 workers.
Results: There were significant reductions in the frequency and severity of musculoskeletal disorder injuries in the screened employee population. Non-screened applicants were 2.38 times more likely to experience a MSD-related overexertion injury specific to the knees, shoulders and back than screened hires (OR = 2.3759; $p = 0.0001$), and incurred 4.33 times higher cost of claims ($p = 0.0003$). Covariates of age, pay type, race and job classification were markedly different between screened and unscreened hires. Among the screened cohort, only the more physically demanding job classifications were significant with field material handlers 7.1 times more likely to experience a non-MSD than less physically demanding workers (OR = 7.1036; $p = 0.0063$).
Conclusions: Objective isokinetic pre-employment screening may significantly reduce injuries in physically demanding jobs. Employees having been effectively matched to the physical demands of their jobs may be at significantly lesser risk of injury and disability from both musculoskeletal and non-musculoskeletal disorders.

Keywords: Isokinetics, employment screening, musculoskeletal disorder injuries, MSDs, physical ability testing, pre-employment testing, ergonomics

1. Introduction

Musculoskeletal disorders (MSDs) involving strains and sprains represent the leading cause of injury and illness in American industry. The US insurance industry places overexertion injuries and illnesses as heading the list of the 10 leading causes of workplace claims [7]. Employees having less than one year on the job, experience 31% of days away from work [22]. The back was most affected by disabling work incidents in almost every industry division. There were 374,700 work-related back injury cases alone in 2003 according to the Bureau of Labor Statistics [23]. Low back musculoskeletal disorders have been estimated to be the costliest work-related injury, equating to $12.3 billion in annual costs for 2000. One study indicated that the figures may be too low as only 25% of workers with cumulative trauma disorders filed workers' compensation claims [1].

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The implementation of ergonomics alone to mitigate the continuing trend of musculoskeletal disorder injuries among physically demanding jobs, while critically important, does not appear to be a complete solution toward workplace injury prevention. Regardless of ergonomic interventions, there may be a continuing gap between the physical demands of the job and the physical ability of a small percentage of workers creating a disproportionate severity of workers' compensation claims costs. NIOSH and OSHA have historically concentrated on the mitigation of MSDs by engineering the workplace to accommodate the worker. Neither of these agencies has placed much emphasis on controlling MSDs by matching workers to their physical job demands; the reverse approach to ergonomics. The relatively recent NIOSH National Occupational Research Agenda for Musculoskeletal Disorders, published in January 2001 [20], did for what appears to be the first time, address "accommodation and functional capacity". The Agenda suggested that "research is needed to determine the effectiveness of interventions directed at matching the individual characteristics, capability, and vulnerability of workers to the work demands".

MSDs have become a serious public health burden, by affecting the ability of American enterprise to safely staff its multitude of physically demanding jobs. Americans continue to physically decondition, which may lead to increasingly higher future rates of strain and sprain injuries and illnesses both on and off the job. Incidence of musculoskeletal injuries has been suggested to be directly related to decreased levels of fitness and cardiovascular conditioning [10]. The evidence is clearly suggesting a direct relationship between fitness, strength level and the propensity for musculoskeletal injury from which ergonomics alone is unable to respond [10,11,16]. Twenty percent of Americans are obese and an additional 40% are overweight. While researchers found the most rapid rise in obesity was among those aged 30–39, significant increases were also noted for those ages 18–29. Obesity is beginning earlier. The number of overweight children and teens has doubled in the last decade and nearly half of youth 12–21 years of age are not physically active [19]. Up to seven in 10 children and young adults, ages six to 17, have below-average cardiovascular fitness, flexibility, and abdominal and upper-body strength, down 11% since 1981 [5] These data may lend support to the continued significance of musculoskeletal disorder claims contrasted by a decreasing trend of overall disabling injuries in the workplace since 1992. Obesity and deconditioning are just two variables influencing physical ability. Pre-existing disease, musculoskeletal joint or neurological disorders further create mismatches between employee physical ability and work demands. Employers cannot effectively discern theses variables through ergonomics intervention.

The chronically high incidences of MSD's clearly indicate that employers are not doing enough ergonomically to reduce MSDs [21]. It has become clear; ergonomics alone will not solve the MSD problem. In summary, industry will have to become more aggressive in either ergonomically reducing physically demanding work to accommodate an increasingly less fit workforce, or consider matching workers fitness to their job demands, or a combination of both.

The work by Chaffin et al. from 1973–1977 (University of Michigan) finding workers three times more likely to be injured on the job when not having demonstrated the required physical work demands, is certainly the cornerstone research in pre-employment physical capability evaluations (PCEs) [3,4,21]. Yu et al reaffirmed this hypothesis in 1984 [24]. There has been surprisingly little formal research since these early authors in evaluating physical capability employment screening in an actual work environment. There are essentially four distinct models for matching human performance to work demands: isometric (static strength testing), isokinetic (dynamic strength testing), work simulation (usually isoinertial evaluation) and functional capacity evaluations. There are an endless variety of testing programs that combine one or more of these models. Few published studies could be found in a Medline literature review for any predictive model of human performance to control MSD injuries in a physically demanding work environment. Most research along this line is unpublished vendor or employer produced data. Overall, results from published studies are inconclusive from either research design or lack of replication from similar studies. There are four studies of any significance that use isokinetics as a predictor of future injury. Mostardi's [14] study of incumbent employee volunteers that excluded those with a history of back pain or surgery was the only published research using isokinetics exclusively for torso (extension) testing where he found no predictive relationship between strength and injury frequency outcome. Drueker [6] and Reimer [17] combined isokinetics with isoinertial testing. While Drueker also found no predictive value between back extension scores and injury outcome, Reimer reported that fitness evaluations may be effective in reducing injuries. Takala's [18] research, also involving incumbent employees and combining isokinetics and isometric evaluations, reported a correlation between pre-test data and injury frequency and severity outcomes only among a cohort having reported a history of back pain. His cohort of previously uninjured or pain-free employees showed no relationship between test scores and injury outcomes. Employees greater than 54 years old were excluded from this study due to probable retirement before the study's conclusion. None of the isokinetic studies evaluated other than the torso, the torso in combination with other joints involved in push, pull, lift or carry tasks, or appeared to correlate data to any large normative database of uninjured workers. A 1995 study prepared by American Airlines [15] was submitted to the Journal of Aerospace Medicine but not published. The airline reported a 92% reduction in isokinetically screened ramp worker's MSDs and over $1 million in savings over seven months compared to unscreened workers' from a previous period.

Littleton [12] employed isoinertial testing for strength and found a significant correlation between pre-hire fitness and reported claims injury frequency and severity. It did not appear from this study, where reductions and savings were reported in raw numbers, that the experimental and control cohorts were standardized for employment exposure in man-hours of work. The actual frequency and severity of losses based on 100 man-year equivalents, for example, may have been more or less than reported.

Mooney [13] and Batti'e [2] studies both involved relatively small sample populations evaluated exclusively by isometric torso (extension) strength testing. Mooney found that strength was not correlated to the incidence of back injuries. Batti'e found that subjects with greater isometric extensor strength actually experienced a higher risk of lumbar injury. Batti'e's cohort, however, was composed of incumbent employee volunteers, exclusive of pre-existing back injury or pain. Harbin [8], the only published study involving a comprehensive functional capacity evaluation as a predictor of future MSD injury, also did not find that isometric extension strength testing alone had a predictive value, but found its post-offer functional capacity evaluation involving 20 anthropometric, strength and fitness components to be predictive of future MSDs.

In this study, the employer, Gypsum Management and Supply Company, had decided to introduce an objective measure of matching workers to the physical demands of their jobs. The authors suggested that data be collected from payroll and workers' compensation loss data to measure the effectiveness of the employment screening model. Our hypothesis in this study was that job applicants meeting predetermined job-related physical capability requirements specific to materials handling will experience a difference in frequency, severity and duration to musculoskeletal disorders.

In the present study, we sought to follow two cohorts of subjects to determine if physical screening using isokinetic dynamometry resulted in differences in musculoskeletal disorder injuries compared to a non-screened control group. The employer selected isokinetics as its preferred form of strength and agility selection based on unpublished employer successes with this technology compared to all other, and possibly, less costly technologies. The study encompassed employees within a large, geographically diversified, building materials supplier engaging in very heavy manual materials handling tasks.

Isokinetics is a form of measuring human muscle performance where maximum tension is generated in the muscle as it contracts at a constant rate of speed over the full range of motion of the joint. In this study, approximately 83% of the body's muscles (knees, shoulders, back) typically engaged in materials handling (push, pull, lift, and carry) were measured.

2. Methods

Our longitudinal study commenced on October 1, 2000, involving new-hires from locations of Gypsum Management & Supply, Inc. (GMS), the largest privately held distributor of drywall in the United States. Two cohorts were created, one composed of newly employed subjects isokinetically screened for physical capability against job demand standards, specific to GMS job classifications, established by a third-party ergonomic consulting group, and the other of non-screened new-hire subjects respectively. Twenty of GMS's 105-yard locations were initially selected for the experimentally screened cohort. These locations across the US had readily available isokinetic testing providers with specialized testing equipment to conduct the pre-employment evaluations and communicate results to a data management company specializing in isokinetic technology for their interpretation. Each work site engaged in nearly-identical work processes and risk factors, using identical materials handling equipment, delivery vehicles, and products. Job descriptions were uniform throughout the company. Requisite applicant skills, knowledge and abilities were uniform in selection criteria among all locations. Subjects, while not randomly enrolled in their respective cohorts, represented widely geographically diversified, yet similar, labor pools across the United States composed exclusively of young (mean age approximately 30 years), racially mixed males. The opportunity for the introduction of bias into the selection process was as limited as possible. As the study progressed, 24 additional sites over the following 33 months were added to the experimental cohort, as local providers randomly became available.

The study was submitted to, and exempted by, an institutional review board in accordance with 45 CFR 46.101(b)(4), as subject data were retrospectively evaluated using only insurance company claims records, personnel records, and the screening vendor's test results (publicly available data/existing data or specimens). The employer's decision to engage in this employment-screening program was independent of the decision to gather and subsequently analyze injury and exposure data.

Subject data was cut-off on June 30, 2003, 33-months from inception, to evaluate our findings.

Experimental subjects were tested on various models of Cybex isokinetic testing and rehabilitation systems as a pre-employment, pre-offer, strength and agility test meeting the Americans with Disability Act's requirements for business necessity and testing job-relatedness reflecting manifest relationship to the employment in question.[1] Each subject's shoulders (bi-laterally), knees (bilaterally) and back (torso) were tested along their full range of motion (flexion and extension) for five repetitions each at 60, 120 and 360 degrees per second.

Approximately eight months following subject cut off, to allow lost-time (indemnity) claims to mature and reflect close-to-ultimate reserving, workers' compensation data was collected from three insurance carriers having participated in underwriting workers' compensation coverage from the study's inception through the 33-month evaluation period. Data was provided electronically directly from the carrier to the authors for data collection and interpretation according to pre-established criteria for data inclusion in accordance with Table 1. The employer provided hire and termination dates for each subject.

GMS contracted for an independent ergonomic job-task analysis (Table 2), of each of the three positions (driver, helper and combination of driver/helper), by a board-certified ergonomist and professional engineer. The results of the job task analyses were provided directly from the ergonomist to the isokinetic data management vendor (iso-vendor) for interpretation and comparison with the US Department of Labor's Dictionary of Occupational Titles, 1991 Revised Edition. The iso-vendor's proprietary strength and agility scoring, based on push, pull, lift, and carry forces required of each respective job, corresponded to the physical work demand classifications of the Dictionary of Occupational Titles. These standards were used exclusively by the iso-vendor to evaluate the pre-employment, isokinetically screened applicants for GMS hiring locations to determine "hire" or "no-hire" status.

GMS yards participating in the experimental screenings were assigned to local authorized providers to which GMS applicants were directed for testing. Test results were provided directly to the GMS hiring manager by the iso-vendor. GMS yards were required to comply with corporate directives of not hiring applicants with test scores below the US Department of Labor "very heavy" (push, pull, lift or carry of >60 pounds frequently or >100 pounds occasionally) threshold established by the job task analyses. GMS corporate paid for tests throughout this study to gain yard management participation.

Neither the study's investigators nor the subject company had any control or influence over the independent test results of each experimental subject taking the new-hire physical capability examination or the design of the job task analyses. The authors could not influence the adjusting, claims reserving, or payment of the worker's compensation claims.

2.1. Statistical analysis

Employees were divided into two groups of isokinetically screened and unscreened workers respectively. The two groups were described by their means $\pm$ standard deviation and frequency on various descriptive measures. Outcome variables were Rate of MSD/Non-MSD injury per person-year, Cost of MSD/Non-MSD injury per person-year, and time to first MSD/Non-MSD injury for a one-year period following employment. The Poisson Regression Model was fitted to the rate of MSD/Non-MSD injury as frequency of injury follows a Poisson distribution. The model was fitted with the offset of the length of employment (L) for the current job by the formula: $\log X_i = \log(L_i) + \Sigma\alpha_k x_{ik}$. Here X_{ik} are covariates

[1] 29 CFR §1630.14(a), Griggs v. Duke Power Co., 401 US 424 (1971).

Table 1
Workers' Compensation Injury Criteria for Recording Occupational Musculoskeletal Disorders (MSDs)

MSD Injury (Knees, shoulders, back)	Work-related injury or disorder to the knees, shoulders, or back involving the muscles, nerves, tendons, joints, cartilage, or spinal column, excluding injuries caused by slips, trips, falls, jumping, struck by or against, or auto accidents, with total incurred costs (combined paid and reserved claims costs) of $1.00 US or greater.
Non-MSD Injury	All work-related MSDs other than to the knees, shoulders, and back and non-MSD injuries, excluding those caused by auto accidents, with total incurred costs of $1.00 US or greater.

Table 2
Summary of Physical Job Requirements – Driver & Helper Positions

Summary of Task Activity	Approximate Maximum Force Requirements
Pull 2-board bundle of wallboard off forks or crane	33–77 kg.
"Back man" supports weight of board is slid off of crane forks. The "back man" holds an estimated 60% of the weight of the board	Estimated 147–301 kg.
Two workers carry a 2-board bundle of wallboard/weight carried per worker.	123–250 kg.
Push force to slide a board bundle of wallboard along plywood floor.	Estimated 66–110 kg.
Push force to slide 2-board bundle of wallboard from a flat stack of wallboard	88–99 kg.
Push and pull loaded wallboard dolly.	48–99 kg.
Push/pull loaded wallboard dolly over irregular surfaces at construction sites.	165–220 kg.
Lifting on a hand-up delivery	123–251 kg.
Lifting by bottom worker on a walk-up delivery	Estimated 275 kg.
Overhead pull force to slide 2-board wallboard bundle off of stack on flatbed truck	33–77 kg.
Lift and carry buckets of dry wall mud.	143 kg.

and $Rate = \frac{X_i}{L} * 365 = \exp[\Sigma\hat{\alpha}_k X_{ik}]$. The odds ratio associated with a covariate was computed as the exponential of the coefficient α_k. An analysis of the survival of employees to first MSD/Non-MSD injury for the two groups was compared using Kaplan Meier curves. The Wilcoxon test (χ^2 distribution) was used to check for differences in survivor functions for the two groups. The Kruskal-Wallis test was used to compare if cost of injury per person year was significantly different for the screened versus non-screened group, the different job descriptions, and forms of compensation, race and age. All statistical tests were performed using 5% level of significance using SAS version 8.1 (SAS Institute Inc., Cary, NC).

3. Results

There were 1944 hired applicants representing more than 105 company locations that were enrolled in the study. Of the 1944 sampled new-hires, 18 were dropped due to incomplete responses. Out of the remaining 1926 subjects (Table 3), 503 met isokinetically screened requirements for physical capability (experimental group) while 1423 subjects were hired without screening (control group). All other hiring parameters between the groups remained similar. The average age of the screened group was 29.81 years with an average length of employment in the current job of 228.92 days or approximately 7.38 months. The average age of the non-screened group was 29.10 years with an average length of employment of 277.85 days or approximately 8.96 months. Of the 1923 subjects (Table 3), 67.55% were White, 30.96% were Black, and less than 1.5% were a combination of Asians, Native American or Others. Approximately 42% of the employees were paid hourly, 11% were incentive- compensated and 46% were paid with a combination of hourly and incentive pay. The majority of employees (87.95%) fell within various "field material handler" job classifications and, due to similarity of work, were lumped into a single group for purposes of evaluation, while 12.05% of the employees were warehouse workers or driver classifications with lesser physical job demands.

3.1. *MSD injuries* (*Table 4 – adjusted odds ratios*)

Table 4 represents the unadjusted and adjusted odds ratios and the covariates-isokinetically screened/non-screened, race, job description grouping, forms of compensation and age. Non-screened workers were 2.38 times more likely to experience an MSD-related overexertion injury specific to the knees, shoulders and back than screened hires (adjusted OR $= 2.3759$; $p = 0.0001$). Overall for MSD injuries, the covariate for age was non-significant. Irrespective of worker screening,

Table 3
Descriptive Statistic of Respondents

Groups	Sample size	Race		Compensation			Age				Job Description	
		White	Non-white	Hourly	Incentive	Combination	Age < 30	Age > 30	Mean	SD	Field Material Handlers	Warehouse/ Drivers
Non Screened	1423	993	430	588	171	664	866	557	29.1036	7.29	1260	163
Screened	503	305	198	213	36	254	265	238	29.8101	6.77	434	69

Table 4
Rate of MSD Injuries

Covariate (X)	Unadjusted Group Rate[1]	Unadjusted odds ratio				Adjusted odds ratio			
		OR $= e^{\alpha}$	95% CI e^{α}		p-value	OR (e^{α})	95% CI (e^{α})		p-value
Isokinetically									
Non-Screened	0.1767	2.379	1.7198	3.2733	0.0001	2.3759	1.7225	3.2772	0.0001
Screened	0.0744								
Age									
Below 30	0.1475	1.0405	0.8339	1.2965	0.7246	1.01745	0.81302	1.2729	0.8795
Above 30	0.1535								
Pay type									
Incentive	0.1627	0.9243	0.6499	1.3148	0.6616	0.7465	0.5251	1.0613	0.1034
Comb	0.1239	0.7042	0.5568	0.8909	0.0035	0.6102	0.4804	0.7750	0.0001
Hourly	0.1760								
Race									
Non Whites	0.1842	1.3785	1.1038	1.7216	0.005	1.4058	1.1209	1.7629	0.0032
Whites	0.1336								
Job Description									
Field Material	0.1611	2.1715	1.3673	3.4486	0.002	2.7069	1.6895	4.3369	0.0001
Warehouse/drivers	0.0742								

[1]Unadjusted Group Rate is $\exp \hat{\alpha}_0$ and $\exp[\hat{\alpha}_0 + \hat{\alpha}_k]$.

combination incentive and hourly paid workers were 0.6102 less likely to experience an MSD than hourly employees, and non-whites were 1.41 more likely than whites for a similar injury. Due to the significance in the odds ratio of screened versus unscreened workers, we extended the hypothesis and divided the sample population by screened and unscreened hires to evaluate the remaining covariates respective to these populations.

3.2. Rate of non-MSD injuries – non-screened workers (*Table 5*)

The rate of non-MSD injuries was not significantly different between screened and non-screened workers. With the exception of pay type, the remaining covariates were significant predictors of non-MSD injuries.

3.3. MSD injuries – screened workers and unscreened workers (*Table 6*)

The remaining covariates: age, pay type, race or job classifications were not statistically significant for MSD injuries among screened hires. These covariates were neutralized by the screening process. For the non-screened group all of the covariates except for age were significantly associated with MSD injuries. The rate of MSD injury for non-whites were 1.33 times greater than whites ($p = 0.0397$); field material handlers had a rate 3.89 times greater than warehouse/drivers ($p = 0.0001$), and hourly workers were 1.82 greater for MSD than the incentive job classifications ($p = 0.0001$).

3.4. Non-MSD injuries – screened and non-screened workers (*Table 7*)

The more physically demanding job grouping of field materials handlers in the screened cohort were over seven times more likely to experience a non-MSD than warehouse/drivers (OR = 7.1036; $p = 0.0063$). All the remaining covariates for the screened group were not significant. Converse to screened workers; pay type was the only non-significant covariate among non-screened workers experiencing non-musculoskeletal disorder injuries. The rate of non-MSD injury for workers below age 30 was 0.7194 times less ($p = 0.0116$) than workers above 30. Non whites were 1.62 times more likely than whites ($p = 0.0002$), and the more physically demanding job grouping rate of non-MSD

Table 5
Rate of Non-MSD injuries

Covariate (X)	Group	Unadjusted odds ratio				Adjusted odds ratio			
	Rate[1]	OR (e^{α})	95% CI e^{α}		p-value	OR (e^{α})	95% CI (e^{α})		p-value
Isokinetically									
Non Screened	0.4236	1.1492	0.9009	1.4659	0.2626	1.1133	0.8723	1.4211	0.3883
Screened	0.3686								
Age									
Below 30	0.3469	0.7659	0.6169	0.9507	0.0156	0.7442	0.5964	0.9288	0.0090
Above 30	0.4529								
Pay type									
Incentive	0.5718	1.457	1.681	1.9875	0.0175	1.1909	0.8708	1.6286	0.2737
Comb	0.3889	0.9909	0.7907	1.2419	0.9368	0.8344	0.6619	1.052	0.1257
Hourly	0.3924								
Race									
Non Whites	0.4926	1.3338	1.07973	1.6476	0.0075	1.4165	1.1391	1.7615	0.0017
Whites	0.3693								
Job Description									
Field Material	0.4466	2.9743	1.7987	4.9182	0.0001	3.0701	1.8281	5.1558	0.0001
Warehouse/drivers	0.1501								

[1]Unadjusted Group Rate $\exp \hat{\alpha}_0$ and $\exp[\hat{\alpha}_0 + \hat{\alpha}_k]$.

Table 6
Rate of MSD injuries for screened/non-screened groups

Covariate (X)	Screened Group				Non-screened Group			
	OR $= e^{\alpha}$	95% CI e^{β}		p-value	OR $= e^{\beta}$	95% CI e^{β}		p-value
Age								
Below 30	0.7941	0.4853	1.2993	0.3585	1.07918	0.8359	1.3932	0.5593
Above 30								
Pay type								
Incentive	0.2011	0.0258	1.5669	0.1257	0.7755	0.5299	1.1349	0.1907
Combination	1.2767	0.7296	2.2298	0.3914	0.5491	0.4172	0.7228	0.0001
Hourly								
Race								
Non Whites	1.3592	0.8246	2.2405	0.2328	1.3293	1.0168	1.7187	0.0397
Whites								
Job Description								
Field material	0.6777	0.3283	1.3989	0.3001	3.8897	2.0812	7.2706	0.0001
Warehouse/drivers								

injury was 2.51 times more than warehouse/driver positions ($p = 0.0013$).

3.5. *Survival to MSD and Non-MSD injury*

Length of employment was significantly different for the two cohorts with non-screened workers having a mean of 278 days compared to 230 for screened hires. While this variance was exclusively created by the non-randomized entry of subjects to each cohort, it did not represent an underlying difference between the groups. Screened workers were enrolled as providers of screening services randomly became available throughout the United States, while non-screened workers were enrolled from a larger population of hiring locations where screening was unavailable. There were fewer screened workers continuously entering the study at later periods than non-screened subjects. Due to this hiring variation, we compared the survival rate of MSD and non-MSD injuries of the screened and non-screened groups at different points of time using Kaplan Meier curves. Survival rate of the two groups were compared at each quartile and at the mean length of employment of the screened worker since this group had the shorter length of employment throughout the study period. Results show that the significance of the p-value increases with each increase in corresponding quartile. Thus at the 25th quartile (Figs 1, 2) there is no significant difference in the survival function of the groups for both MSD (Wilcoxon $\chi^2 = 0.3848$, $p = 0.5350$) as well as non-MSD injuries (Wilcoxon $\chi^2 = 0.6243$, $p = 0.4294$). However, as we approach the average length of employment we find that there is a significantly higher survival function for screened work-

Table 7
Rate of Non-MSD injuries for screened and non-screened groups

Covariate (X)	Screened Group				Non-screened Group			
	OR $= e^{\alpha}$	95% CI e^{β}		p-value	OR $= e^{\beta}$	95% CI e^{β}		p-value
Age								
Below 30	0.8904	0.5832	1.3594	0.5908	0.7194	0.5517	0.9277	0.0116
Above 30								
Pay type								
Incentive	0.5199	0.1866	1.4487	0.2109	1.3311	0.9496	1.8658	0.0971
Combination	1.0267	0.6601	1.5966	0.9069	0.7735	0.5883	1.0172	0.0660
Hourly								
Race								
Non Whites	1.1104	0.7149	1.7245	0.6411	1.6227	1.2639	2.0933	0.0002
Whites								
Job Description								
Field material	7.1036	1.7383	29.0283	0.0063	2.5121	1.4974	4.4054	0.0013
Warehouse/drivers								

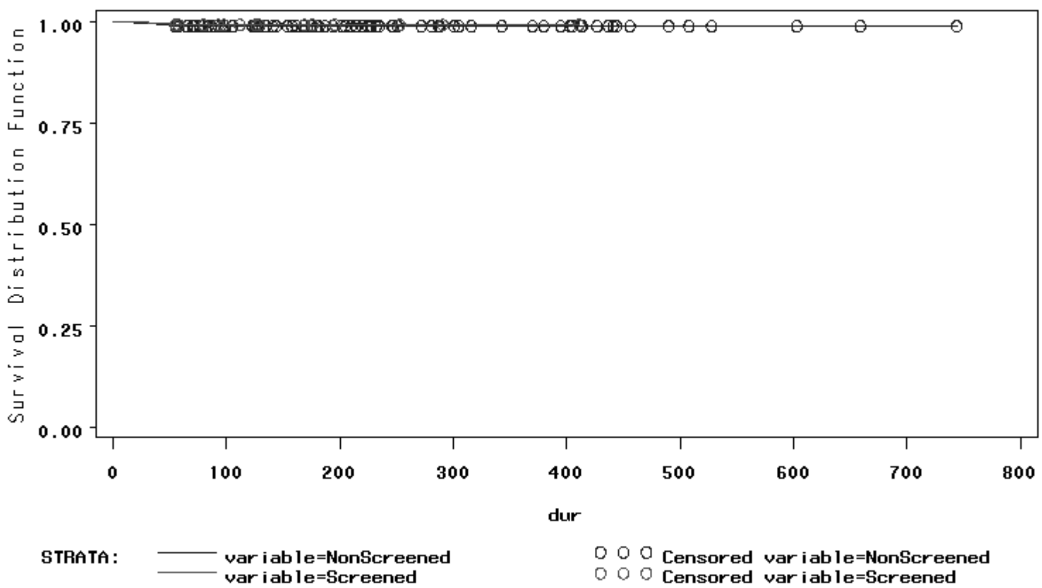

Fig. 1. MSD injury free survival for screened and non-screened groups at the 25th percentile.

ers for non-MSD injuries (Wilcoxon $\chi^2 = 4.2704$, $p = 0.0388$) than for non-screened workers. The difference did not hold for MSD injuries (Wilcoxon $\chi^2 = 0.7786$, $p = 0.3776$) (Figs 3, 4). However, at the third quartile (Figs 5, 6) there is a significantly higher survival rate for screened workers than for non-screened workers for both MSD injuries (Wilcoxon $\chi^2 = 4.1438$, $p = 0.0418$) as well as non-MSD injuries (Wilcoxon $\chi^2 = 4.0788$, $p = 0.0434$). For the one year period, the Kaplan Meier survival curves (Figs 7, 8) also demonstrated significant differences in the survival function of MSD injuries between the screened and the non-screened group (Wilcoxon $\chi^2 = 3.8920$, $p = 0.0485$). Similar differences (Wilcoxon $\chi^2 = 5.3918$, $p = 0.0211$) among the screened and the non-screened group were seen for non-MSD injuries.

3.6. *Cost of MSD/Non-MSD injuries per person-year (Table 8)*

The Kruskall-Wallis results indicate that the average cost of $422.76 for non-screened workers was

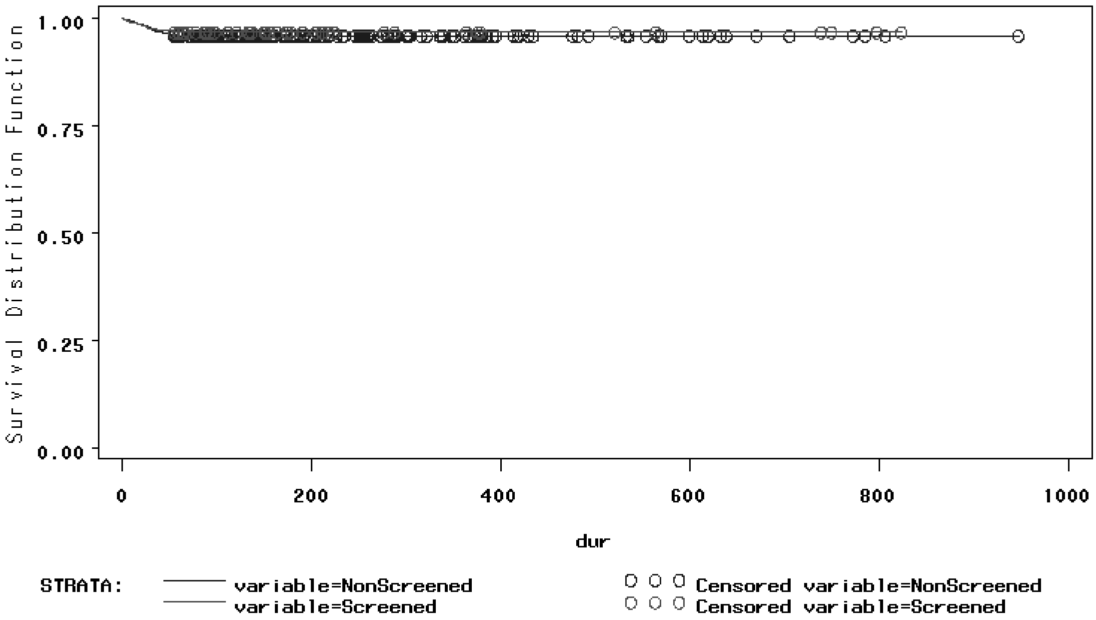

Fig. 2. Non-MSD injury free survival for screened and non-screened groups at the 25th percentile.

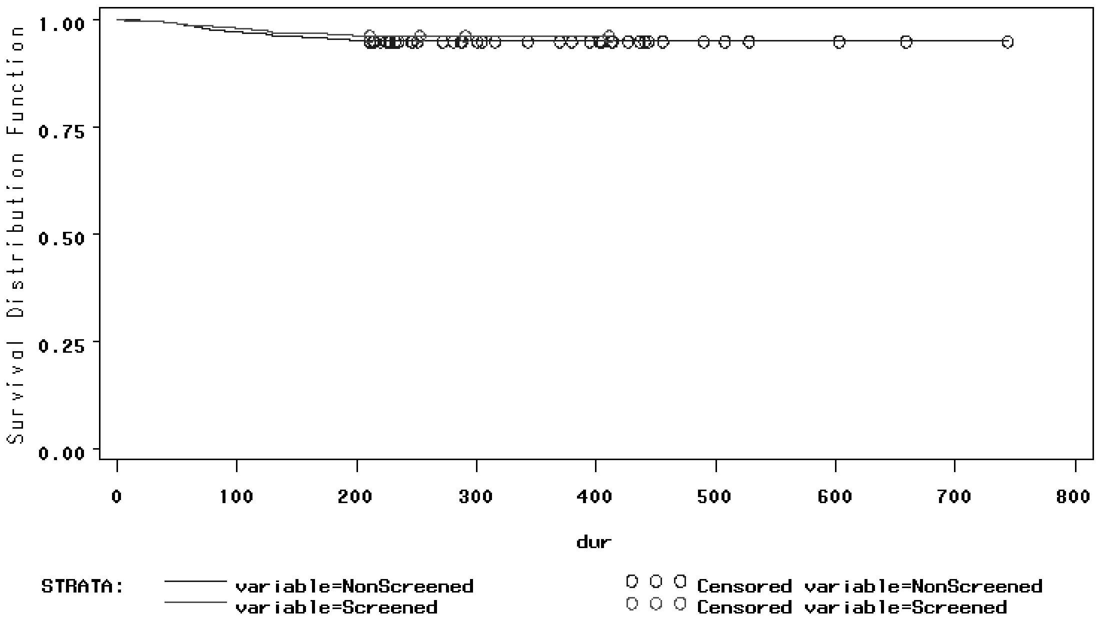

Fig. 3. MSD injury free survival for screened and non-screened groups at mean.

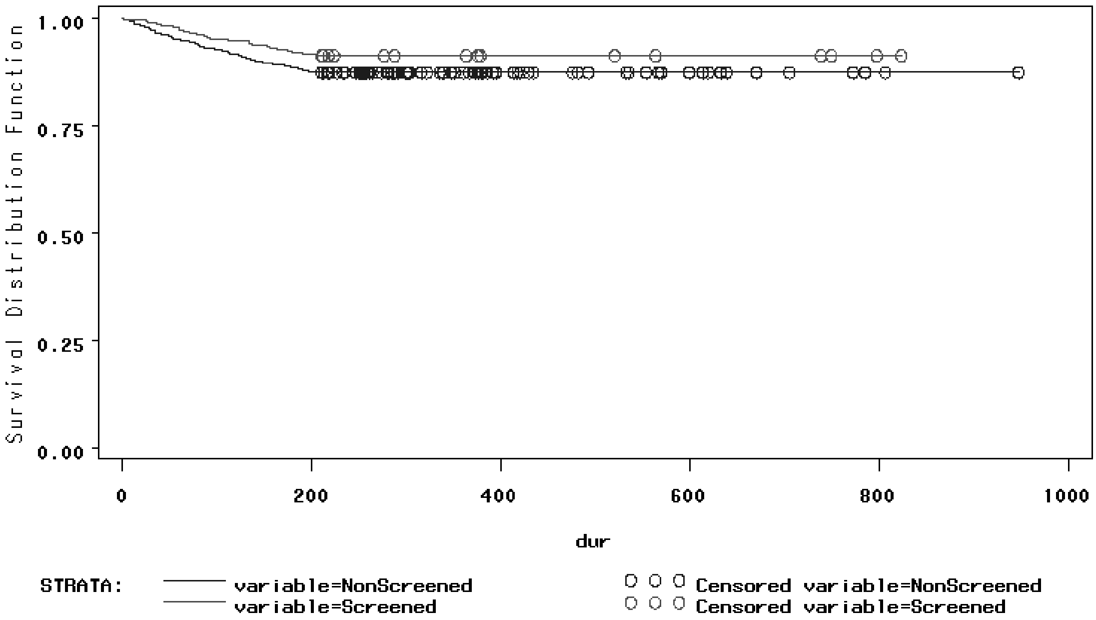

Fig. 4. Non-MSD injury free survival for screened and non-screened groups at the mean.

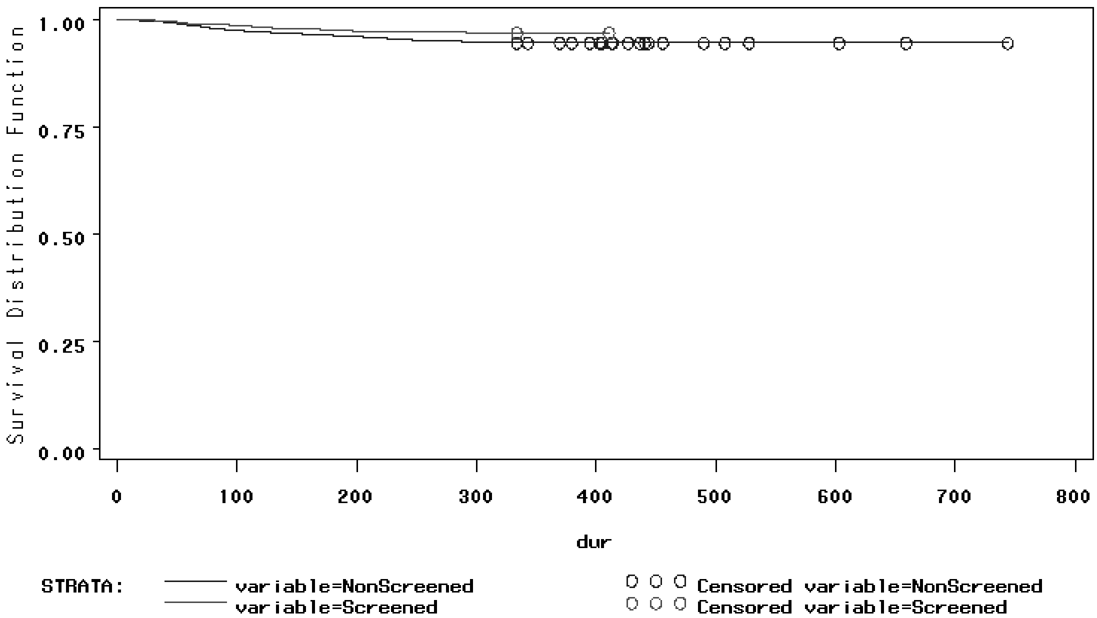

Fig. 5. MSD injury free survival for screened and non-screened groups at the 75th percentile.

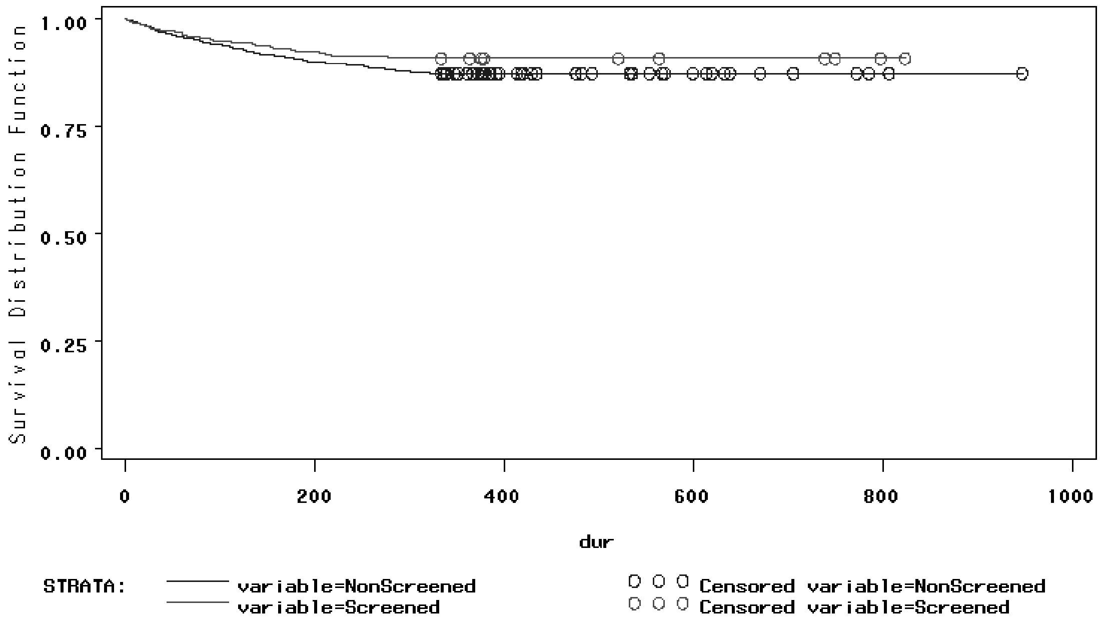

Fig. 6. Non-MSD injury free survival for screened and non-screened groups at the 75th percentile.

4.33 times higher for MSD injuries ($p = 0.0003$) than screened workers who had an average cost of $97.63 per year (Table 8). While there was no statistically significant association between the frequency of screened versus non-screened workers to non-MSD injuries, there was a significantly higher cost of claims (10.62 times higher) ($p = 0.0063$) experienced by the non-screened workers. Non-screened workers experienced an average cost of $2464.20 compared to only $231.91 per year for screened hires. There was no significant difference in cost of MSD/Non-MSD injuries for race, forms of compensation, job description or age.

4. Discussion

Our results show significant reductions in both the rate (frequency) and cost (severity) of musculoskeletal disorders in a population of isokinetically-screened workers in very physically demanding jobs. Findings from this study suggest that employees properly matched to the physical demands of the job will experience significant reductions in frequency and severity of musculoskeletal injury involving the knees, shoulders and back. In reality, females seldom apply for work in the very heavy category of physical demands as was the case with this employer. Regardless, very heavy physically demanding jobs would create a disparate impact against females and typically those with certain disabilities. Such practices are permitted under EEOC regulations and interpretations where the employer can show it is necessary to have such standards for the safety of the applicants.[2] There were significant differences indicated from the additional analysis conducted separately for the screened and unscreened employees. Physically matched workers to physical job demands were unaffected by pay type, job classification, age or race while non-screened workers experiencing musculoskeletal disorder injuries were affected by pay type, race and job classification. This seems to imply that as pertains to physical qualifications, isokinetically-screened applicants may be hired without threat of bias, specifically relative to race, pay type and job classification. A secondary benefit may be the substantially lower costs in non-MSD claims expense among screened workers. While there was no significance in claims frequency involving non-MSD

[2] 433 US at 329 (1977), 93 S. ct. 1817 (1973), 1991 WL 1187127 (EEOC).

Table 8
Cost of MSD/Non-MSD injuries per person year

Variables	MSD Injuries		Non-MSD Injuries	
	Kruskal-Wallis χ^2	p-value	Kruskal-Wallis χ^2	p-value
Isokinetically				
Screened	12.8967	0.0003	7.4750	0.0063
Non-Screened				
Race				
Whites	0.2219	0.6376	0.3257	0.5682
Non-Whites				
Job Description				
Job1	0.6821	0.4089	2.9291	0.0870
Job2				
Age				
Below 30	0.9694	0.3248	0.7655	0.3816
Above 30				
Pay type				
Incentive	3.5896	0.1662	0.2019	0.9040
Combination				
Hourly				

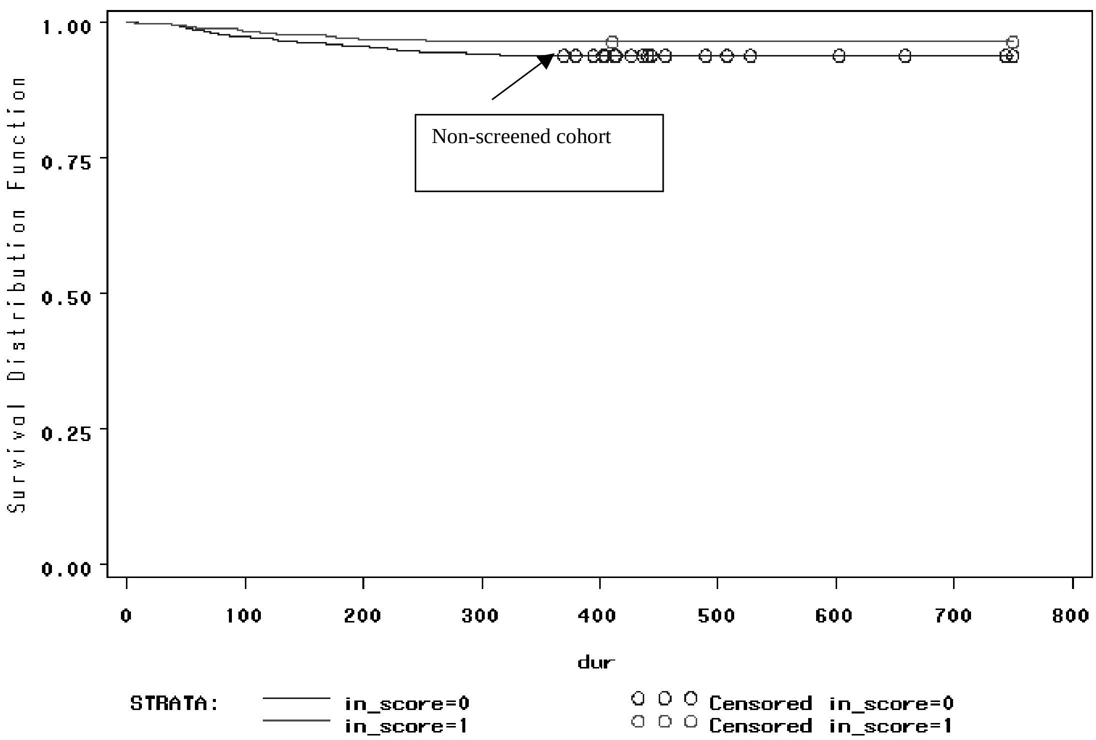

Fig. 7. MSD injury free survival for screened and non-screened groups for one year.

injuries among screened workers, there was a 10-fold reduction in the average loss incident cost that warrants further investigation with additional studies. Without the aid of further research, it is difficult to draw an association between physically matched workers and the substantially lesser incident cost per non-MSD claim.

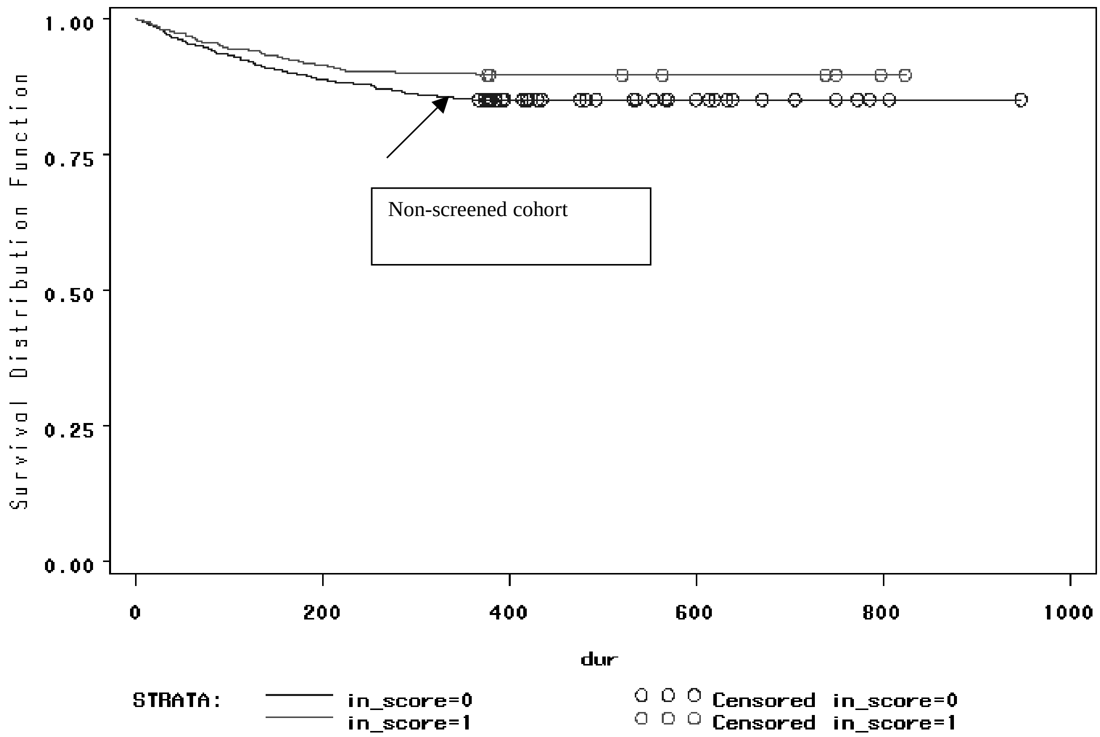

Fig. 8. Non-MSD free survival for screened and non-screened groups.

Although length of employment does affect survival rate for injuries, survival analysis run at different points of length of employment demonstrated significant differences in duration to MSD as well as non-MSD injuries between the screened and the non-screened groups. Future research, however, should focus on testing for differences in survival function for screened and non-screened subjects who are matched on length of employment. The employer experienced an annual employee turnover rate of approximately 32.17%. The results indicate that isokinetic screening significantly increases survival to first MSD as well as non-MSD injuries.

This study evaluated MSD injury development between screened and unscreened hires in one of the most strenuous occupations in America. We believe our findings have broad generalizability to very physically demanding jobs within all industrial sectors, as the screenings are a specific measure of muscle and joint strength and range of motion generalized to specific joint forces required of a job and not tied to any specific job task. As concluded by Innes [9], "the further a work-related assessment moves away from the actual work environment and requirements of a specific job, the greater its level of standardisation and generalisability. Conversely, when work-related assessments occur in the actual work environment, qualitative processes are used, and results are specific and non-generalisable." The data suggest that employees, regardless of job demands, who are physically mismatched and incapable of performing the minimal essential physical work requirements, will become injured at a higher frequency and severity than those properly matched to their jobs. The economic consequences of significantly reducing musculoskeletal disorders involving approximately 83% of the body's muscle groups engaged in the materials handling process (knees, shoulders and back), through a relatively low-cost employment screening tool can be profound. The humanitarian consequences of reducing short, long-term and permanent disability among workers by the broad use of an objective physical capability matching protocol may even be larger. However, physically demanding jobs will remain to be filled by physically capable workers. Labor pool gaps may be created by the large-scale application, and consequent applicant job disqualification, from employment screening. This creates a potential social problem to be addressed by government and industry alike.

5. Conclusions

Our findings support a strong causal relationship between physical capability employment screening utilizing the application of isokinetic technology and the significant reduction of musculoskeletal disorders to the knees, shoulders and back. Employees having been effectively matched to physically demanding jobs are possibly at significantly less risk of injury and disability. Organizations with recognizable exposures to jobs on the high end of physically demanding tasks may wish to consider the addition of physical capability employment screening to their overall risk management program. While the primary conclusions of this study are well supported by very low, test statistics' p-values, more reproducible studies are needed.

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