Spine

SPINE Volume 38, Number 25, pp 2208-2215

OPEN

A New Pre-employment Functional Capacity Evaluation Predicts Longer-Term Risk of Musculoskeletal Injury in Healthy Workers

A Prospective Cohort Study

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Study Design. Prospective cohort study.

Objective. To determine if a job-specific pre-employment functional assessment (PEFA) predicts musculoskeletal injury risk in healthy mineworkers.

Summary of Background Data. Traditional methods of pre-employment screening, including radiography and medical screenings, are not valid predictors of occupational musculoskeletal injury risk. Short-form job-specific functional capacity evaluations are increasing in popularity, despite limited evidence of their ability to predict injury risk in healthy workers.

Methods. Participants were recruited from an Australian coal mine between 2002 and 2009 as part of the hiring process. At baseline, participants were screened with the JobFit System PEFA, and classified as PEFA 1 if they met job demands and PEFA>1, if not. Males who completed the PEFA and were employed were included. Injury data from company records were coded for body part, mechanism, and severity. The relationship between PEFA classification and time to first injury was analyzed using Cox proportional hazards regression with adjustments for department and *post hoc* stratification for time (0–1.3 yr, 1.3–6 yr).

Results. Of the 600 participants (median age, 37 yr, range, 17.0–62.6 yr), 427 scored PEFA 1. One hundred ninety-six sprain/strain injuries were reported by 121 workers, including 35 back injuries from manual handling. Significant differences between PEFA groups were found in time to first injury for all injury types during the long term (any injury: adjusted hazard ratio [HR] = 2.3, 95% confidence interval [CI] = 1.4–3.9; manual handling injury: HR = 3.3, CI = 1.6–7.2; any back injury: HR = 3.3, CI = 1.6–6.6; back injuries from manual handling HR = 5.8, CI = 2.0–16.7), but not during the short term. An area under the receiver operator curve value of 0.73 (CI = 0.61–0.86) demonstrated acceptable predictive ability for back injuries from manual handling during the long term.

Conclusion. JobFit System PEFAs predict musculoskeletal injury risk in healthy mineworkers after 1.3 years of employment. Future research should assess whether use of these assessments as part of a holistic risk management program can decrease workplace musculoskeletal injuries.

Key words: musculoskeletal diseases, functional capacity evaluation, occupational injuries, physical fitness, back injuries, pre-employment screening, manual handling, risk management.

Level of Evidence: 2

Spine 2013;38:2208–2215

Musculoskeletal injuries in the workplace continue to be a significant economic and social problem in industrial nations worldwide.[1–4] For the Australian mining industry, for example, musculoskeletal injuries account for the largest proportion of workplace injury claims (44%), with body stressing (manual handling) being the most common mechanism of injury (42%) and the back being the most common body part involved (19%).[5] Pre-employment screening that endeavors to identify individuals who are at greater risk of sustaining an injury is one method used in an attempt to reduce workplace injuries. Traditional methods of screening, such as back radiography and medical screenings including strength, flexibility, endurance, and body composition testing have not been shown to predict subsequent injury risk.[6–9] Many researchers in the field of workplace injury prevention have highlighted the need for job-specific assessments.[10–13] It is also a requirement of antidiscrimination legislation in many jurisdictions that work-related assessments test against the inherent requirements of the job.[14–19]

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Acknowledgement date: March 5, 2013. First revision date: June 23, 2013. Second revision date: August 28, 2013. Acceptance date: August 29, 2013.

The manuscript submitted does not contain information about medical device(s)/drug(s).

Australian Coal Association Research Program (No. C14045) grant funds were received in support of this work.

Relevant financial activities outside the submitted work: board membership, employment.

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DOI: 10.1097/BRS.0000000000000013

Functional capacity evaluation (FCE) testing has traditionally been used in rehabilitation and medicolegal assessments, but generally not in the pre-employment phase because of time and cost restraints. A short-form FCE, comprising only a core selection of functional activities, is more practical with the development of injury or job-specific FCEs now recently adopted in the rehabilitation arena.[20–22] Although more validity research is needed, recent evidence for the predictability of return to work of injured workers using short-form FCEs is promising.[23–24] However, very limited published evidence is available to justify their use as a predictor of injury in healthy workers. Even with traditional long-form FCE methods, a recent Cochrane Review[25] concluded that there is minimal quality evidence for functional testing in pre-employment screening, despite their increasing use for this purpose. The aim of this research is to evaluate the validity of a job-specific pre-employment functional assessment in terms of its ability to predict musculoskeletal injury risk in healthy mine workers in the Australian coal mining industry.

MATERIALS AND METHODS

Design

This prospective cohort study investigates the relationship between participants' performance in a job-specific JobFit System PEFA and their subsequent workplace musculoskeletal injury history. Participant PEFA performance and demographic information were collected at the time of the assessment. Employment data and injury statistics were collected during and at the conclusion of the study period. This project was cleared in accordance with the ethical review guidelines at The University of Queensland by the School of Human Movement Studies Ethics Committee.

Participants

A coal mine with underground and open cut operations, employing more than 1000 workers, participated in the study from 2002 to 2009. As part of the hiring process, all prospective employees were required to participate in a job-specific PEFA. Prospective employees from all operational areas and all occupation types were eligible to participate.

Exclusion criteria included:

- Current injury or injury requiring medical treatment, time off work or restricted duties in the previous 6 weeks.
- Current Worker's Compensation Medical Certificate.
- Blood pressure higher than 145 mmHg (systolic) or 95 mmHg (diastolic).
- Current or past history of a cardiac condition.
- Surgery, fractures, or dislocations within the previous 6 months.

All participants (n = 1019) signed an informed consent outlining assessment components, risk, and expectations of submaximal physical testing and the precautions that would be taken, the purpose of the assessment, the use and disclosure of the collected information, and the opportunity to discontinue testing at any time.

Female employees (n = 95) were excluded, as were participants who were not successful in their job application. The reason for unsuccessful employment was not disclosed to the researcher by the employer, and it is not known what influence the PEFA score had on this decision. Male participants who completed the assessment, were hired and employed in the job related to their PEFA assessment were included, resulting in data from 600 participants for analysis (Figure 1).

Outcome Measures and Data Collection

Pre-employment Functional Assessment

The JobFit System PEFA was used to conduct the job-specific functional assessments. The test components and criteria for the PEFAs were specific for the job for which the participant was applying. The functional demands of the tasks had been previously assessed by a physiotherapist using observation and interview techniques and were broken down into 42 postural tolerances measures and 21 manual handling measures. Task demands were collated using the JobFit System software to produce job demands. Postural job demands that were used for the PEFA criteria in this study included: reaching forward, reaching above shoulder, stooping, squatting, and stair climbing. These were selected on the basis of the job requirements and injury history at the workplace. Manual handling job demands included floor, bench, shoulder and above shoulder lifts, and bilateral carry. The maximum weight requirement for each manual handling measure for each job was used as the assessment criteria.

Each PEFA contained the following test components and was delivered in the same sequence: musculoskeletal screen, aerobic fitness test, postural and dynamic tolerances (job specific), and manual handling tasks (job specific). The job-specific PEFAs could have any combination, and any number, of the postural tolerances and manual handling listed earlier, however, components were always delivered in the same sequence. A functional lifting approach was used. In general, the PEFA is completed within a 1-hour timeframe. Testing procedures were fully explained to the participant prior to

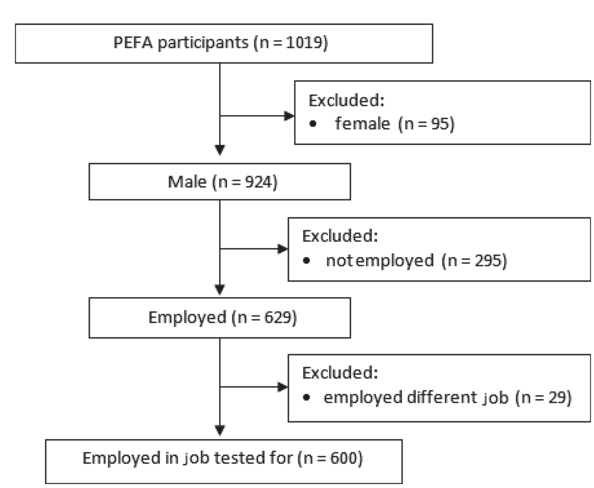

Figure 1. Flow chart illustrating the study recruitment process. PEFA indicates pre-employment functional assessment.

commencement and were consistent with those outlined in the JobFit System Training Program.[26]

PEFAs were conducted by a physiotherapist, occupational therapist, or exercise physiologist. Performance on the postural and dynamic tolerances tasks and the manual handling tasks were compared with the job demands to determine the JobFit System PEFA score. The reliability of the JobFit System PEFA has been evaluated and reported previously,[27] and was considered suitable with excellent intrarater reliability (intraclass coefficient [ICC], 0.94; CI, 0.90–0.96) and good inter-rater reliability (ICC, 0.84; CI, 0.75–0.90).

JobFit System PEFA Score

The JobFit System PEFA score (range, 1–4) is the overall score of the worker's performance in comparison with the physical demands of the job for which they are applying:

- Score 1: Has demonstrated the functional capacity to perform the proposed position as described with no restrictions.
- Score 2: Has demonstrated the functional capacity to perform the proposed position as described with minimal restrictions.
- Score 3: Has demonstrated the functional capacity to perform the proposed position as described with moderate restrictions.
- Score 4: Has not demonstrated the functional capacity to meet the inherent requirements of the proposed position as described.

Prior to statistical analysis, raw PEFA data collection sheets from workers who had been injured at work since the time of their PEFA, were reviewed and scored by a blinded independent third party. Of the 121 records reviewed, disagreement was found between the original scoring and the reviewer's scoring for 15 participants. Agreement on the scoring was reached through discussion between the researcher and the auditor.

Sociodemographic Records

Sociodemographic characteristics including age, job, and department were collected. Employment records including start and finish dates and the job in which the applicant was employed were provided by the company's human resources department.

Injury Data

Injury reports for study participants were retrieved from the company's accident and incident database. The injury database used in the study is the central repository for all accidents and incidents that occur at the company. Employees are legally obligated to report all incidents to their supervisor for entry into the database. The company maintains clear definitions for the coding of the injury data. This database captures injuries that may not progress to a workers' compensation claim and was therefore more complete than Workers' Compensation data. Injury severity was in the range from no treatment required through to lost time from work. All severity classifications were considered an injury. The aim of the functional assessment was to identify musculoskeletal injury risks arising from overexertion and consequently the analysis was restricted to injuries coded as "sprain/strain."

Each narrative record was individually reviewed and coded by the researcher in 3 categories: (1) body part, (2) mechanism of injury, and (3) severity of injury. Injury codes were reviewed by a blinded independent third party for all injured participant records (n = 196). Differences occurred for 31 records before agreement was reached by discussion between the researcher and auditor.

Time from commencement of employment to date of injury was also recorded. In the event that a participant recorded more than one injury during the study period, data from all injuries was captured, and data regarding the first injury of its type was included in the analysis. Neither prior medical history nor workers' compensation data at the time of the PEFA, nor that reported by the participant during the medical clearance process were permitted to be captured.

Data Analysis

Relative risk was calculated for PEFA score and each injury type. The relationship between PEFA score and time to first injury was studied using Cox proportional hazards regression. PEFA scores were dichotomized to PEFA 1 (met job demands) and PEFA>1 (did not meet job demands) groups for the analysis. The models were analyzed unadjusted and with adjustment for confounders. Potential confounders (*i.e.*, age, job, and department) were added to the model one-by-one, and if it changed the regression coefficient by more than 10%, the variable was included in the adjusted model. Using this selection method, only department was included as a confounder. The Cox proportional hazards model assumes that the hazard ratio (HR) is constant over time. This assumption was checked and the log-minus-log curves and models with time-dependent covariates showed an interaction with time consistently for all outcomes. Therefore, further *post hoc* analyses were stratified for time with the cutoff for time set at 1.3 years based on the log-minus-log curves. HRs were presented for 0 to 1.3 years (shorter term) and 1.3 to 6 years (longer term) separately. To estimate the predictive ability of the PEFA to discriminate between participants with and without injury, the area under the receiver operator curve (AUC) was calculated with 95% confidence intervals. An AUC of 1 indicates perfect discriminative ability, whereas an AUC of 0.50 indicates that the discriminative ability is equal to chance. All analyses were done using IBM SPSS Statistics version 20 for Windows. *P* values were based on 2-sided tests and were considered statistically significant at $P < 0.05$.

RESULTS

Participant Characteristics

Of the 600 participants, 427 met the job demands and scored PEFA 1 (71%) (Table 1). Of the remaining 173 workers, 107 scored PEFA 2 (18%), and 66 (11%) scored PEFA 3. No workers scored PEFA 4. Because of the small numbers,

TABLE 1. Characteristics of Participants

Characteristic	Participants			P
	Sample (n = 600)	PEFA=1 (n = 427)	PEFA>1 (n = 173)	
Age (yr), median (IQR)	37.0 (29.0–45.0)	36.4 (28.9–44.3)	38.6 (29.2–47.6)	0.08
Time in study (yr), median (IQR)				
All participants	2.0 (1.2–4.0)	2.0 (1.3–4.0)	2.0 (0.9–4.0)	0.82
Left during study	1.5 (0.7–2.5)	1.6 (0.8–2.5)	1.2 (0.5–2.5)	0.54
Remained in study	2.4 (1.5–5.5)	2.4 (1.7–5.6)	2.4 (1.2–5.3)	0.97
Department, n (%)				<0.001
CHPP	20 (3)	6 (1)	14 (8)	
Open cut	285 (48)	242 (57)	43 (25)	
Professional	61 (10)	59 (14)	2 (1)	
Underground	139 (23)	55 (13)	84 (49)	
Workshop	95 (16)	65 (15)	30 (17)	
ASCO code, n (%)				<0.001
Laborers	106 (18)	47 (11)	59 (34)	
Production	265 (44)	233 (55)	32 (19)	
Professional	62 (10)	60 (14)	2 (1)	
Tradespersons	167 (28)	87 (20)	80 (46)	

Department explanatory notes:

- *CHPP is a multistory facility accessed via multiple stairs that washes and prepares coal for transport; workers are predominantly engaged in operating, maintaining, and repairing infrastructure and conveyor belts and may also spend some time in the control room or operating heavy mobile plant such as dozers.*
- *Open cut is the surface mining operations; workers are predominantly engaged in operating heavy mobile plant equipment including rear dump trucks, dozers, graders, water trucks, light vehicles; a smaller number operate electric shovels and draglines.*
- *Professional is the office work environment; workers are predominantly engaged in administrative type activities, but may also participate in field inspections and supervision in the other departments, including accessing and egressing equipment and operating light vehicles.*
- *Underground is the underground mining operations; workers are predominantly engaged in physical labor and operating, servicing, and repairing machinery in standing, walking, and seated positions, which are often awkward with frequent manual handling; ground and light conditions are poor.*
- *Workshop is a surface maintenance and repair facility for heavy mobile plant; workers may also be required to perform activities in the field on uneven ground with seasonal temperature variations; working postures are often awkward with frequent manual handling.*

ASCO code explanatory notes:

- *Laborers are generally unskilled blue-collar workers.*
- *Production workers are generally skilled heavy mobile plant operators.*
- *Professionals include administration, engineers, surveyors, geologists, managers, and similar roles.*
- *Tradespersons are skilled electricians, auto electricians, mechanics, fitters, boilermakers, and welders.*

PEFA indicates pre-employment functional assessment; CHPP, coal haul processing plant; ASCO, Australian Standard Classification of Occupations.

participants with scores 2 and 3 were collapsed into one group: PEFA>1 (n = 173) for subsequent analysis. Of the 295 workers who were not employed, 69.2% scored PEFA 1 (n = 204).

The median age at time of PEFA was 37.0 (IQR, 29.0–45.0; range, 17.0–62.6) years. There was no significant association between age at time of PEFA and PEFA score ($P = 0.08$). The mean duration of employment during the study period was 2.7 years (SD, 2.1). The PEFA groups differed in department of employment ($P \leq 0.001$) and occupation type ($P \leq 0.001$) (Table 1).

Injury Rates

During the study period from December 2002 to December 2009, a total of 196 sprain/strain injuries were reported by 121 workers. Injury rates per person year for each body location and mechanism of injury are reported in Table 2.

The highest injury rate by body location was injuries to the back/trunk (43 per 1000 person years). Manual handling had the highest injury rate by mechanism of injury at 46 per 1000 person years. Back and trunk injuries associated with manual handling were the largest subgroup (22 per 1000 person years).

TABLE 2. Sprain and Strain Injuries by Mechanism of Injury and Body Location

Body Location	Mechanism of Injury							
	Manual Handling	Ground Conditions	Operating	Climbing	External Force	Other	Subtotal	Incidence Rate per 1000 Person Years
Back/trunk	35	3	22	3	5	2	70	43
Neck	1	0	6	1	10	0	18	11
Shoulder	17	0	0	4	0	0	21	13
Arm	9	3	0	2	1	0	15	9
Wrist/hand	6	0	1	0	0	0	7	4
Knee	3	16	0	8	0	0	27	17
Ankle	0	15	0	9	0	0	24	15
Other	4	4	1	3	1	1	14	9
Subtotal	75	41	30	30	17	3	196	
Incidence rate per 1000 person years	46	25	19	19	10	2		

PEFA Score and Injury Risk

A significant increase in relative risk exists for workers who score PEFA>1 for any injury type with the greatest relative risk being for any back injury from manual handling (RR, 3.0; 95% CI, 1.4–6.1) (Table 3).

Statistically significant differences were found between PEFA groups in time to first injury during the longer term, but not the short term, for all injury types (Table 3). These relationships remained significant after adjustment for confounders. The interaction between PEFA and department was not significant with results presented for the total group only. During the long term, risk of injury was 2.3 times greater in the PEFA>1 group than the PEFA 1 group (CI, 1.4–3.9) but was not significant in the shorter term. Significant group differences were also found for injuries resulting from manual handling (HR, 3.3; CI 1.6–7.2) and for back injuries (HR, 3.3; CI, 1.6–6.6). The greatest difference in injury risk was observed for back injuries resulting from manual handling during the longer term, with the likelihood of sustaining an injury being 5.8 times greater in the PEFA>1 group than in the PEFA 1 group (CI, 2.0–16.7) (Figure 2). Although acknowledging that the study was underpowered to analyze the predictive value of the individual PEFA scores, an explorative analyses was done, which showed that the HRs were higher for PEFA 2 (HR = 8.8; CI, 2.9–26.3) than PEFA 3 (HR = 3.6; CI, 0.9–15.1), suggesting no linear dose-response relationship. However, confidence intervals were wide and results should be interpreted with care.

The AUC as a measure of the predictive ability of the PEFA for each injury type in the short and long term is presented in Table 3. Moderate levels were demonstrated during the longer

TABLE 3. Relationship Between PEFA Score and Injury Risk

Injury Type	PEFA 1 (%)	PEFA>1 (%)	RR (95% CI)	Adj. HR ≤1.3 yr (95% CI)*	Adj. HR 1.3–6 yr (95% CI)*	AUC ≤1.3 yr (95% CI)	AUC 1.3–6 yr (95% CI)
Any injury	71 (20)	50 (40)	1.7 (1.2–2.3)	1.3 (0.7–2.1)	2.3 (1.4–3.9)	0.54 (0.47–0.62)	0.63 (0.55–0.71)
Any manual handling injury	27 (7)	25 (17)	2.2 (1.3–3.8)	0.9 (0.4–2.1)	3.3 (1.6–7.2)	0.52 (0.40–0.64)	0.69 (0.58–0.80)
Any back injury	33 (8)	23 (15)	1.7 (1.0–2.8)	0.6 (0.2–1.8)	3.3 (1.6–6.6)	0.46 (0.35–0.58)	0.66 (0.55–0.76)
Any back injury from manual handling	13 (3)	16 (10)	3.0 (1.4–6.1)	0.9 (0.3–3.2)	5.8 (2.0–16.7)	0.52 (0.36–0.69)	0.73 (0.61–0.86)

**Adjusted for department.*

PEFA indicates pre-employment functional assessment; RR, relative risk; Adj. HR, adjusted hazard ratio; AUC, area under the receiver operator curve; CI, confidence interval.

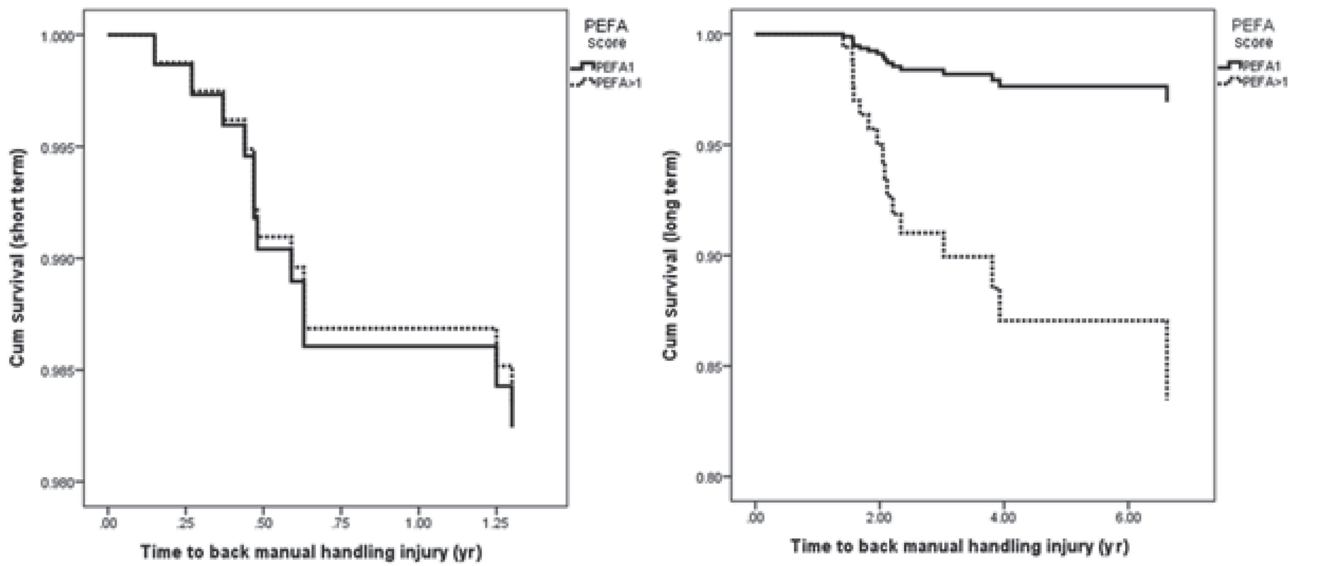

Figure 2. Comparison of survival plots for back injury from manual handling injury by PEFA score during short and long term. PEFA indicates pre-employment functional assessment; Cum, cumulative.

term, with an acceptable predictive ability of the PEFA for back injuries from manual handling confirmed with an AUC value of 0.73 (CI, 0.61–0.86).

DISCUSSION

Performance in a job-specific PEFA predicted risk of any injury, any back injury, any manual handling injury, and any back injury from manual handling in a group of 600 Australian coal mine workers during the longer term, but not in the short term. The association between the JobFit System PEFA and injury risk was strongest for the risk of back injuries associated with manual handling. This is the first study to demonstrate the validity of job-specific PEFAs in healthy coal miners, and also the first to identify a change in musculoskeletal injury risk profile over time and for different injury types.

The research has a number of limitations, including restricted access to information such as previous injury history, chronic diseases, and educational background that have previously been reported as confounding factors in musculoskeletal injuries.[6,23,28] The assumption of the accuracy of the company's injury records may be a study limitation; however, there is no reason to predict any reporting bias as a function of PEFA score. The potential positive influence of concurrent risk management strategies employed at the workplace (*e.g.*, equipment and task redesign, use of personal protective equipment, and risk management training), as well as potential negative influencers (*e.g.*, productivity demands, variable mining conditions, and shift work including 12-hour shifts), could also not be controlled, however both participant groups were exposed to the same influencers. Further research at additional workplaces and in different industries is required to demonstrate the generalizability of the findings.

A notable difference between this and other studies investigating the validity of pre-employment functional testing was the identification of a change in injury risk profile over time. The longer duration of this study and mean employment time of the participants in comparison with others[13,29–31] enabled this trend to be investigated. This study identified what could be described as an initial "honeymoon period" after which time the participant's risk of first injury increased dramatically. Further research is needed to attempt to determine the reason why this increased risk occurs; however, possible hypotheses include increased rate of musculoskeletal deterioration as a result of working at maximum capacity for an extended period; decreased worker and/or employer awareness of, or compliance with, restrictions advised at the time of testing or commencement of employment; further deconditioning from inactivity or other factors; or, behavioral change of the worker toward more risk-taking activities on the assumption that "they had 'survived' thus far and therefore the predictions were wrong." Until such evidence is identified, health professionals, workers, and employers can maximize the opportunity of the "honeymoon period" as a time for physical conditioning, behavioral safety programs, and workplace modifications in an attempt to reduce the worker's risk of injury proactively rather than the negative option of not hiring.

A second distinguishing feature of this study was the measurement and identification of variable risk profiles for different injury types. Although the PEFA was predictive of 4 different categories of musculoskeletal injuries, it was most predictive of manual handling injuries, and possibly had the strongest prediction for back injuries associated with manual handling because of the number of included activities that tested back function. However, numbers of this last type of injury were low and validation of the current results in a different sample is needed to confirm these findings. Further research into the predictive ability of components of the

PEFA, rather than just the overall score, on different injury types and body locations in healthy workers may give insight into which items are the most predictive and how the PEFA may be shortened or improved.

As discussed by Serra *et al*,[32] the implementation of pre-employment testing programs is a balancing act between protecting a worker and their colleagues from harm, and against protecting them from discrimination. Assessments that are job-specific, objective, and validated play a large role in maintaining that balance, especially when they are part of a holistic risk management program including ergonomic redesign, behavioral safety, and individual health improvement programs.

CONCLUSION

These results indicate that the JobFit System PEFA may be a valid predictor of time to first injury risk in healthy workers and could be used by employers as part of a holistic injury prevention program. More research is needed to determine the mitigating factors during, or the attenuating factors after, the initial honeymoon period during which the workers' injury risk was lowest. Likewise additional research is needed to identify which components of the JobFit System PEFA are more predictive of different injury types and body locations than others.

➢ Key Points

- ❑ There is limited evidence regarding the validity of functional testing in healthy workers as a predictor of workplace injury.
- ❑ This study indicates that the job-specific JobFit System PEFA is a long-term predictor of workplace musculoskeletal injury risk.
- ❑ The association between the JobFit System PEFA and injury risk was strongest for the risk of back injuries associated with manual handling during the longer term.

Acknowledgments

The authors thank the contribution of the health and safety and human resources personnel from the test site for their assistance in data collection, and Ms. Janet Cawte for her assistance as a third-party reviewer of test data. The authors also thank the participants in the study, the mine owner, and management team for allowing them to conduct the study at their workplace.

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