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Can fitness and movement quality prevent back injury in elite task force police officers? A 5-year longitudinal study

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Elite police work has bursts of intense physically demanding work requiring high levels of fitness, or capacity, and movement competency; which are assumed to increase one's injury resilience. The purpose of this study was to follow members of an elite police force ($N = 53$) to test whether back injuries ($N = 14$) could be predicted from measures of fitness and movement quality. Measures of torso endurance, relative and absolute strength, hip ROM and movement quality using the Functional Movement Screen$^{\mathrm{TM}}$ and other dynamic movement tests were obtained from every officer at baseline. When variables were grouped and considered holistically, rather than individually, back injury could be predicted. Seven variables best predicted those who would suffer a back injury (64% sensitivity and 95% specificity for an overall concordance of 87%). Overall, the ability to predict back injury was not high, suggesting that there is more complexity to this relationship than is explained with the variables tested here.

Practitioner Summary: Members of elite police forces have exposure to intense physically demanding work. Increased levels of fitness and movement competency have been assumed to increase injury resilience. However, complexity in the interactions between exposure, movement competency, training, fitness and injury may occlude the true relationship between these variables.

Keywords: predicting injury; back pain; fitness; strength; range of motion; assessment; FMS

Abbreviations: BEND, Segmental lateral bend movement test; BOX, Box lift movement test; BSE, Biering-Sorensen; COIN, Coin lift movement test; EEXT, Hip extension with knee extended range of motion test; EFLX, Hip extension with knee flexed range of motion test; EROT, External rotation hip range of motion test; ETF, Emergency Task Force; EXT, Segmental extension movement test; FEXT, Hip flexion with knee extended range of motion test; FFLX, Hip flexion with knee flexed range of motion test; FLEX, Segmental flexion movement test; FMS, Functional movement screen™; FPLK, Front plank; GAIT, Gait movement test; GRP, Grip strength; HRD, Hurdle step movement test; IROT, Internal rotation hip range of motion test; LNG, In-line lunge movement test; PEL, Pelvis rock movement test; POS, Standing posture movement test; PUP, Pull-ups; PUSH, Trunk stability push-up movement test; ROT, Rotary stability movement test; SHDR, Shoulder mobility movement test; SIT, Static sit-up posture test; SLDL, Single leg deadlift; SLR, Active straight leg raise movement test; SLSQ, Single leg squat; SPLK, Side plank; SPOS, Seated posture movement test; SQT, Deep squat movement test; TORS, Torsion control movement test; TWST, Segmental twist movement test

Introduction

Police work, in particular the work of elite Emergency Task Force (ETF) units, has potential for bursts of highly intense, physically demanding work. Officers in these units train for a considerable amount of time to prepare themselves for challenges they may face while on duty. Efforts are made to improve the specific skills necessary to meet job requirements together with fitness for 'physical preparedness'. The ability to perform physically demanding tasks while avoiding injury has been linked to both fitness levels (e.g. in firefighters, Cady, Bischoff, and O'Connell 1979) and movement patterns [e.g. better movement reduces joint loads and injury occurrence in the knee (e.g. in athletic populations, Hewett et al. 1999) and in the back (e.g. in occupational populations, McGill et al. 2003)].

It is assumed that being fit and 'moving well' reduces the risk of back injury within many occupations. Movement competency not only includes having the capability to move in patterns that reduce tissue stress concentrations, but also includes choosing patterns that avoid the accumulation of tissue microdamage. Poorly chosen or executed movement patterns create tissue stresses that lead to both acute and chronic injury. Past studies have tested specific variables for their direct relation to occupational work exposure and for enhancing resilience from injury. For example, variables such as poor torso muscle endurance (Biering-Sorensen 1984), reduced hip range of motion (ROM) (Ashmen, Swanik, and Lephart 1996) and poor movement quality (Kiesel, Plisky, and Butler 2009b) have been linked to higher injury rates. This has

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*Corresponding author. Email: mcgill@uwaterloo.ca motivated the development of tests such as the Functional Movement Screen™ (FMS), a seven-task test proposed to evaluate joint mobility and stability (Cook, Burton, and Hoogenboom 2006a, 2006b) within movement patterns.

The purpose of this study was to assess the links between specific components of fitness and movement ability of a cohort of police officers with subsequent injury over a substantial period of time. Quasi-static tests such as the FMS which are constrained, together with unconstrained task competency that tests the appropriateness of a certain choice of movement pattern were quantified. Additional variables including torso muscle endurance, relative and absolute strength and hip mobility were also quantified for their possible relationship with subsequent injury.

Methods

Study design

In this prospective cohort study, subjects were measured at baseline on a variety of fitness variables, range of motion and tasks to measure movement competency. Over a 5-year follow-up period, the subjects were monitored for back injury. Injury was defined as any back injury not due to any specific acute incidents such as trips, slips, falls and other accidental mechanisms. Only new injuries over the observational period were self-reported through follow-up forms. Thus, existing injury or injury history prior to baseline were not included in this analysis. The methodology for the baseline data collected over 5 years ago was described in McGill et al. (2013) and the interested reader is directed to this reference for full details. The key elements are repeated in this 5-year follow-up paper.

Subjects

Members of the elite ETF of a major city Police Department were recruited and all participated. The response rate for those who stayed on the force over the 5 years was 100% ($N = 53$). All were male, ([mean, 1 standard deviation] age, 37.9 ± 5.0 years; height, 1.8 ± 0.1 m; body mass, 88.7 ± 12.1 kg; and BMI, 27.6 ± 2.1 kg/m^2) and had years of active duty, 13.4 ± 5.2; weight training experience, 15.7 ± 6.7 years; and a perceived fitness, 7.5 ± 0.8 (scale of 1–10). Each participant read and signed an informed consent form approved by the University Office for Research Ethics (Table 1).

Baseline data collection

Testing sessions lasted approximately 2.5 h for each participant and were performed prior to team training sessions. Tests were conducted in a random order.

Fitness testing

Fitness tests evaluated static muscular endurance (static sit-up posture, front plank, side planks/bridges and Biering-Sorensen extension following the protocol of McGill, Childs, and Liebenson 1999, 2010) together with absolute and body-size normalised strength (e.g. grip strength is an absolute strength measure while pull-ups to task failure are dependent upon the ability to handle one's own body weight) (Figure 1). Guidelines for test administration were provided in detail in McGill et al. (2013) for: (1) static sit-up posture (SIT), (2) front plank (FPLK), (3) side plank (SPLK), (4) Biering-Sorensen extension (BSE), (5) grip strength (GRP), (6) pull-ups (PUP). Approximately 5 min of rest was given between each task, which has shown to be sufficient so as not to influence results of subsequent tests (McGill, Childs, and Liebenson 1999).

Table 1. Subject information.

	Injured		Non-injured	
Subject information	Mean	SD	Mean	SD
Age (years)	38.4	6.2	37.7	4.6
Height (cm)	175.5	10.4	180.0	7.7
Weight (kg)	85.8	11.8	89.7	12.3
BMI	27.7	1.9	27.6	2.2
Active duty (years)	13.1	4.3	13.6	5.5
Weight training (years)	15.7	7.2	15.7	6.6
Perceived fitness	7.6	0.7	7.5	0.9

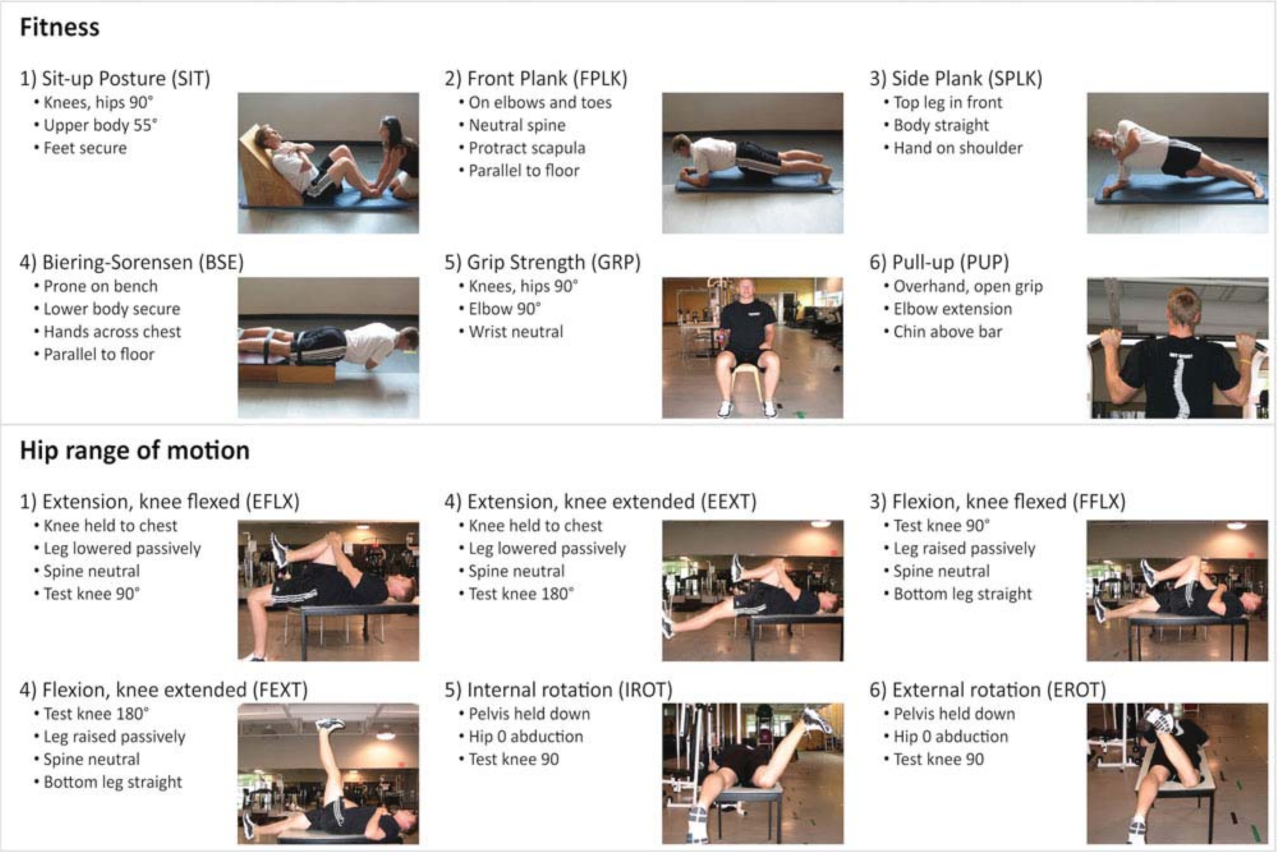

Figure 1. The fitness tests (including measures of torso muscle endurance) and the hip range of motion tests.

Range of motion testing

Restricted hip motion has been linked to future injury (Ashmen, Swanik, and Lephart 1996), thus passive hip range of motion (flexion, extension and internal and external rotation) was assessed with six tests (Figure 1): (1) hip extension (knee flexed) (EFLX), (2) hip extension (knee extended) (EEXT), (3) hip flexion (knee flexed) (FFLX), (4) hip flexion (knee extended) (FEXT), (5) hip internal rotation (IROT), (6) hip external rotation (EROT). All tests including ROM tests were performed by the same person with 12 years of experience in orthopaedic goniometry.

Movement competency screening

Twenty general tests were conducted to assess movement competency (Figure 2). These included the seven tests that comprise the FMS (tasks 1–7) that was developed as a tool thought to quantify some aspects of movement competency (documented by Cook, Burton, and Hoogenboom 2006a, 2006b). Thirteen additional movement tests were chosen to reflect tasks often used by clinicians to evaluate injury risk (after McGill 2007) or return to work status. The 20 tasks were: (1) deep squat (SQT), (2) hurdle step (HRD), (3) in-line lunge (LNG), (4) shoulder mobility (SHDR), (5) active straight leg raise (SLR), (6) trunk stability push-up (PUSH), (7) rotary stability (ROT) [note that 'clearing' tests were included with the SHDR, PUSH and ROT tasks to expose other potential sources of pain (after Cook, Burton, and Hoogenboom 2006a, 2006b)], (8) standing posture (POS), (9) seated posture (SPOS), (10) segmental flexion (FLEX), (11) segmental extension (EXT), (12) segmental lateral bend (BEND), (13) segmental twist (TWST), (14) gait (GAIT), (15) box lift (BOX), (16) coin lift (COIN), (17) single leg deadlift (SLDL), (18) single leg squat (SLSQ), (19) torsion control (TORS), and (20) pelvis rock (PEL) (after Sahrmann 2002).

Data analysis

Movement competency for the seven FMS tasks was graded using the guidelines published by Cook, Burton, and Hoogenboom (2006a, 2006b). The inter-rater reliability for the FMS has shown to be high (Minick et al. 2010); therefore,

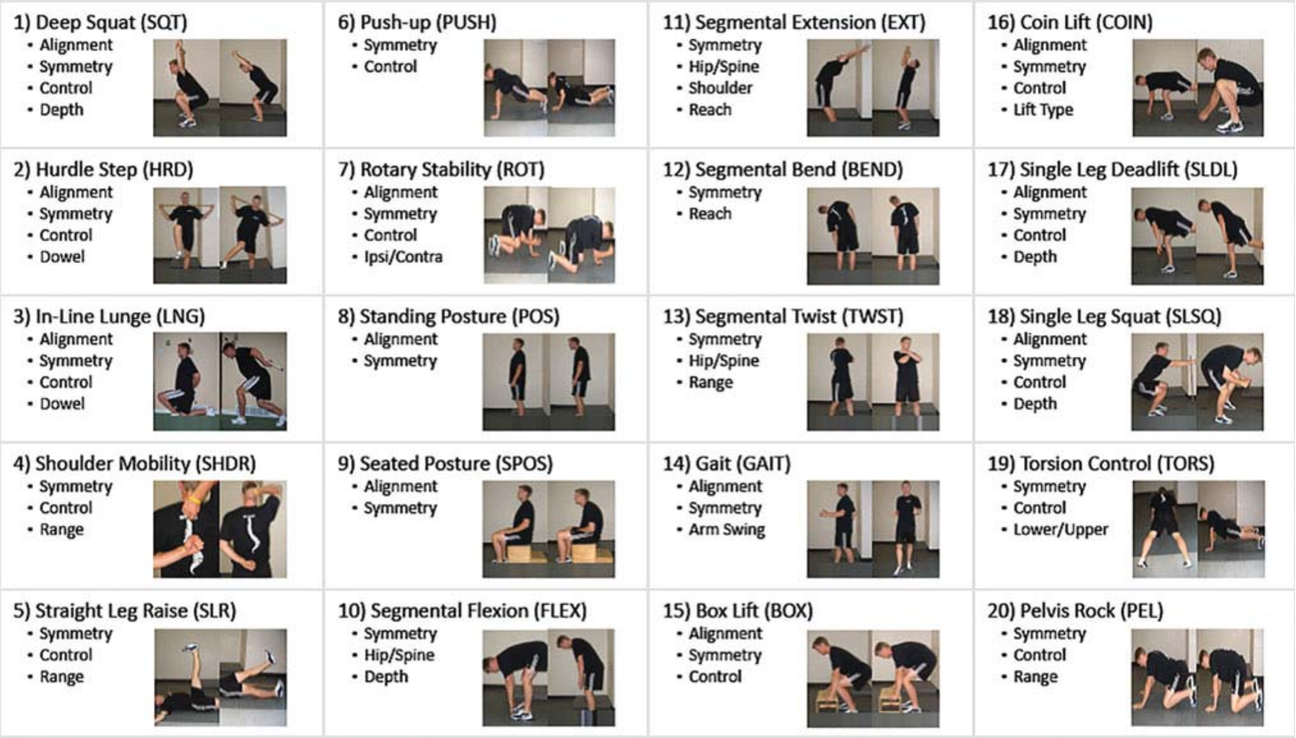

Figure 2. The movement competency tasks. Note that tasks 1–7 comprise the FMS.

one clinician with 5 years of movement screening experience graded all tests. Scores of 0–3 were assigned to each task (based on explicit criteria) to differentiate between movements performed with or without compensatory motion and pain after Cook, Burton, and Hoogenboom (2006a, 2006b). Extensive descriptions of the scoring system for the other movement tasks are provided for the interested reader in a comparison paper (Frost et al. 2013). However, briefly, a score of three, two, one and zero represented performed without compensation (according to relevant criteria), performed with compensation, could not perform (according to relevant criteria) or pain, respectively. The cumulative sum of all tasks was defined as the total movement competency score. Since a total FMS score equal to or lower than 14 has been suggested as an indicator in past studies (e.g. O'Connor et al. 2011), a contingency table was constructed using an FMS score of 14 as the break point 'risk factor'.

Statistical analyses

All statistical procedures were performed using SPSS version 21 (SPSS Inc., Chicago, IL). Initially independent *T*-tests were performed on all independent variables to provide a rough idea of where the signal strength resided. These results were used to obtain an initial impression only. Using this knowledge, a backward Wald stepwise regression was performed on grouped subsets of independent variables, so as to minimize the ratio between the number of subjects and independent variables. The subsets of independent variables were grouped into five categories: subject information, fitness tests, hip ROM, movement competency tasks and only the FMS tasks.

Results

Over the 5-year follow-up period, 14 of the 53 participants sustained a back injury. When each single variable was considered in the *T*-test analysis, having more abdominal endurance was the most highly associated with injury ($p = 0.078$), and a poor competency score with Shirley Sahrmann's pelvic rock test (Sahrmann 2002) being the second most linked to back injury ($p = 0.083$). While these generally unimpressive *p*-values providing an initial impression, they justified the regression analysis on grouped variables.

The binary logistic regression was performed on the four subsets of grouped variables (fitness, hip ROM, movement competency and FMS movement competency) that when considered together could predict injury. The first subset (fitness variables) produced the model that best predicted those who would eventually sustain a back injury (see Tables 2–5). The

Table 2. This was the best model ($p = .009$) it predicted 36% of injuries.

	Injured		Non-injured	
Fitness variables	Mean	SD	Mean	SD
Sit up posture (s)*	162.4	77.6	131.3	46.0
Front Bridge (s)	169.0	52.9	150.6	52.1
Biering-Sorensen (s)*	107.7	27.4	108.0	28.6
SIT/BSE*	1.51	0.68	1.29	0.53
Right-side bridge (s)*	87.0	21.2	77.2	26.9
RSB/BSE	0.83	0.19	0.74	0.26
Left-side bridge (s)	85.1	20.7	76.7	20.9
LSB/BSE	0.82	0.21	0.74	0.23
Right grip strength (kg)	56.0	6.6	55.9	9.2
Left grip strength (kg)	54.0	4.0	52.6	8.3
Pullups	11.6	4.6	10.6	2.8

Note: Included in the model were higher scores on the sit up posture, RSB and SIT/BSE ratio; and a lower score on the Biering-Sorensen. Injured are more fit.

Table 3. Model ($p = .03$) predicted 14% of the injuries.

	Injured		Non-injured	
Hip ROM	Mean	SD	Mean	SD
TT flexed right	2.6	12.6	4.5	8.6
TT flexed left*	4.4	11.5	3.7	9.2
TT extended right*	−0.78	11.9	3.6	10.0
TT extended left	1.0	11.8	3.7	11.0
Unilateral hip flexion flexed right	113.9	13.6	111.3	14.4
Unilateral hip flexion flexed left	112.9	11.8	108.7	19.7
Unilateral hip flexion extended right	88.6	21.9	98.2	18.0
Unilateral hip flexion extended left	87.4	20.8	94.1	17.2
Prone int. rot. right	19.3	19.3	20.2	12.4
Prone int. rot. left	17.8	17.8	17.0	8.7
Prone ext. rot. right	32.8	32.8	28.9	9.4
Prone ext rot. left	31.6	31.6	31.4	12.1

Note: It implies asymmetries between the left and right hips exemplified by the Thomas test flexed left and Thomas test extended right being the variables comprising this model.

Table 4. Model ($p = .03$) predicted 21% of injuries.

	Injured		Non-injured	
Movement competency	Mean	SD	Mean	SD
Standing posture	2.1	0.3	2.0	0.2
Sit to stand	2.4	0.5	2.6	0.5
Gait	2.1	0.3	2.1	0.4
Segmental flexion*	2.3	1.1	2.5	0.7
Segmental extension	2.0	0.7	2.1	0.7
Segmental lateral bend*	2.6	0.5	2.4	0.7
Segmental twist	2.7	0.5	2.6	0.7
Box lift	2.5	0.5	2.5	0.5
Coin lift*	2.4	0.8	2.0	0.9
Single leg deadlift	2.4	0.5	2.4	0.5
Single leg squat	2.1	0.8	2.4	0.7
Torsion control	2.7	0.5	2.5	0.5
Pelvis rock*	1.8	0.9	2.2	0.8
Total score	30.0	3.96	30.5	3.06

Note: It included higher scores on the coin lift and segmental lateral bend; and a lower score on the pelvis rock and segmental flexion.

Table 5. No model was created and none of the injuries were predicted.

	Injured		Non-injured	
FMS	Mean	SD	Mean	SD
Overhead squat	1.5	0.9	1.5	0.8
In-line lunge	2.2	0.6	2.3	0.7
Hurdle step	2.6	0.5	2.6	0.5
Active straight leg raise	2.2	0.7	2.0	0.7
Shoulder mobility	1.4	1.0	1.4	0.7
Trunk stability pushup	2.4	0.5	2.6	0.5
Rotary stability	2.9	0.4	2.7	0.5
Total	15.1	2.4	15.1	2.1
Overall movement	45.1	5.6	45.5	4.7

Table 6. FMS and back injury sensitivity analysis.

	Exposure to risk factor	
Back injury	Yes (≥ 14)	No (< 14)
Yes	10	4
No	26	13
Total	36	17

Note: Sensitivity = 0.28, specificity = 0.76. Score of 14 was the best cutoff. Coin flip would have predicted injury better. Risk Factor – FMS Score ≥ 14. Outcome – back injury.

final model of fitness variables contained 4 of the total 11 variables: SIT, BSE, SIT/BSE (the ratio of the SIT time in seconds over the BSE time) and the RSPLK. Greater endurance times on the SIT and RSPLK, along with a decreased endurance time on the BSE contributed to the model ($p = 0.009$, $\chi^2 = 13.601$, $R^2 = 0.330$), predicting injury with 36% sensitivity (five of the injuries were predicted) and 92% specificity, for an overall concordance of 77%.

The hip measurements subset of variables produced a model ($p = 0.025$, $\chi^2 = 7.414$, $R^2 = 0.191$) containing two variables, the left EFLX and the right EEXT. A decreased score on the EEXT, and an increased score on the EFLX predicted injury with 14% sensitivity, 95% specificity and an overall concordance of 74%.

When all the 20 movement competency tasks were considered together, the model ($p = 0.029$, $\chi^2 = 10.794$, $R^2 = 0.269$) predicted injury with 21% sensitivity, 95% specificity and 76% concordance. The model contained four variables: FLEX, BEND, COIN and PEL.

The seven movement tasks of the FMS were then considered as their own subset. No model emerged from the regression analysis and none of the injuries were predicted. Contingency tables (Table 6) had the ability to predict back injury, based on an FMS score of 14 or less, with a 28% sensitivity, and 76% specificity, and to predict all injuries produced a 42% sensitivity and 47% specificity.

Following the regression analyses performed on each subset (as described above), the predictive variables that emerged from each were grouped and entered into a regression analysis of their own. Logically one could argue that this is the most important and revealing regression ($p < 0.001$, $\chi^2 = 26.561$, $R^2 = 0.581$). A higher sensitivity in terms of predicting back injury was produced (64%) with the seven variables: SIT, BSE, SIT/BSE, RSPLK, EFLX, EEXT and PEL. The specificity was 95% and the overall concordance was 87%.

Discussion

The success of the outcome of this study to predict injury based on fitness and movement competency depends on the perspective of the reader. On the one hand, predicting 64% back injuries could be considered as explaining enough variance to warrant suggestions for intervention and prevention. On the other hand, if these scores were used in the context of assessing individual elite police officers to determine if they are candidates for injury, the predictions are not overly impressive. Flipping a coin would predict with a 50% error rate. A good medical screen should be able to correctly identify those who eventually get the disease or injury 9 times out of 10. The variables listed here were able to predict 6.4 times out of 10. Thus, the study suggests that a substantial amount of variance in back injury incidence was explained with torso muscle endurance, hip asymmetry, and the pelvic rock test, but as a medical screen for use with individuals it was still weak.

However, while 64% injuries were predicted, the model was much better at predicting those who did not sustain a back injury with 95% correctly predicted.

Although some studies have suggested that being fitter reduces the risk of injury, there are several alternate explanations that could obscure the true relationship. Several recent studies have suggested that injuries in firefighters are occurring during training at the firehall (Poplin et al. 2012). Our observations over the past 5 years with the group of police officers is that they are aggravating injury in the weight room during strength and conditioning sessions. Thus, the 'fitter' officers may have higher exposure to musculoskeletal risk given their training, obscuring the link between fitness and movement competency, and injury rates. Recent studies on firefighters strengthen this hypothesis for exposure (Frost et al. 2013) together with a smaller study on a basketball team where the better players (being fitter and better athletes) had double the playing time and higher injury rates (McGill, Andersen, and Horne 2012). Discussion subsequent to the Cady et al. study on firefighters (1979) several decades ago may still be relevant today. They showed that although the fitter firefighters had fewer injuries, when they did become injured their injuries were more severe. It is possible that fitter firefighters were the ones who did the demanding jobs on a fire crew increasing their injury risk exposure. Interestingly, psychologists of the day suggested in conference meetings when discussing this landmark study that there is a psychological profile consistent with being fit that causes the 'more fit' to complain less about smaller injuries. Thus the observation of more severe injuries could have been a self-perception and reporting artifact. Recent reports from the military (Lisman et al. 2013) suggested that soldiers with a total FMS score less than 14, or greater than 17, (in other words those with the poorest and highest movement competency) reported higher subsequent injury rates during several weeks of intense basic training. This observation may be explained with this notion of there being an optimal level of fitness for injury resilience. Specifically, too low a level causes tissue damage as they have not been trained to meet the demand, while the training to create a high level of fitness combines with the job demands causing cumulative trauma to run ahead of the rate of repair.

As noted in the introduction of this paper, a lack of torso extensor muscle endurance is predictive of injury (Biering-Sorensen 1984). This notion was supported by the data in this study. Furthermore, while less hip range of motion has been suggested as predictive of back injury (e.g. Ashmen, Swanik, and Lephart 1996), this study suggested that asymmetry in hip motion is important. While measures of hip asymmetry obtained from the FMS tests (such as the straight leg raise) were not revealed as significant in the analysis, the more severe Thomas tests of differences between hip sagittal motion did. Finally, the pelvic rock test of Shirley Sahrmann completed the best predictive model for back injury.

Several limitations impinge on the interpretation of the data reported here. Some studies have reported a high ability to predict injury (e.g. Hewett et al. 2005). However, these studies were of specific populations at risk for specific injuries, in this case female basketball players and ACL injury. Over several years they isolated the injury mechanism (frontal knee motions) and then incorporated the specific injury mechanism into their injury screening test. Back injury probably has many more mechanisms being more non-homogeneous so that predicting injury will be more challenging. This study lasted 5 years and tracked 14 injuries, and predicted them quite well. Had the study been conducted for longer than 5 years, the prediction rate may have changed, however, this is one of the longest studies reported to date. This is a major asset of this paper, nonetheless it remains a limitation that the injuries were self-reported and their specific nature was not known; even though we suspect that the toughness required for the job would mitigate against the reporting of more minor injuries. Further, although officers trained each day together, the specific exercises and possible variation in programme design was unknown. Finally, some of the variables and tests may be redundant and simply correlate of being fit. For example, one would suspect that fitter people score higher on tests of movement competency, yet have higher exposure to tissue overload in the effort to become fit. This notion appears consistent with the 'U'-shaped function that governs the majority of biological variables – optimal health is achieved where each variable converges on the optimal level of not too much or not too little.

In summary, injury prediction is complicated. The complexity of interaction between exposure, movement competency, training and fitness occludes the relationship between these variables. Nonetheless the ability to predict back injury is one of the highest reported over a 5-year follow-up period.

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Disclosure statement

No potential conflict of interest was reported by the authors.

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