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Original Article

Functional Movement Screen as a Predictor of Occupational Injury Among Denver Firefighters

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A B S T R A C T

Background: The Functional Movement Screen (FMS™) is a screening tool used to assess an individual's ability to perform fundamental movements that are necessary to do physically active tasks. The purpose of this study was to assess the ability of FMS to predict occupational injury among Denver Fire Department firefighters.

Method: FMS tests were administered from 2012 to 2016. Claim status was defined as any claim occurrence vs. no claim and an overexertion vs. no claim/other claim within 1 year of the FMS. To assess associations between FMS score and claim status, FMS scores were dichotomized into $\leq$14 and $>$ 14. Age-adjusted odds ratios were calculated using logistic regression. Sensitivities and specificities of FMS predicting claims at various FMS score cut points, ranging from 10 to 20 were tested.

Results: Of 581 firefighters (mean $\pm$ SD, age 38 $\pm$ 9.8 y) who completed FMS between February 2015 and March 2018, 188 (32.4%) filed a WC claim in the study time frame. Seventy-two of those (38.3%) were categorized as overexertion claims. There was no association between FMS score and claim status [odds ratio (OR) = 1.27, 95% confidence interval (CI): 0.88 − 1.83] and overexertion claim vs. no claim/other claim (OR = 1.33, 95% CI: 0.81 − 2.21). There was no optimal cutoff for FMS in predicting a WC claim.

Conclusions: Although the FMS has been predictive of injuries in other populations, among this sample of firefighters, it was not predictive of a future WC claim.

1. Introduction

In 2018, there were nearly 60,000 occupational injuries among firefighters in the United States. That year, over a third (38%) of all injuries that occurred at the fireground and over half (59%) of nonfireground injuries were a sprain, strain, or muscular pain type of injury [1]. Owing to the physical nature of the job, much of the research in injury prevention among firefighters has focused on physical fitness [2]. Lower levels of physical fitness, which is comprised of cardiovascular fitness, muscular strength, muscular endurance, flexibility, and body composition are associated with higher injury risk. Those who are less fit are at particular risk for sprain and strain injuries [3]. In 2014, Poplin et al. [4] found a slight association between worse VO_2max, a measure of cardiovascular fitness, and increased injury occurrence among firefighters.

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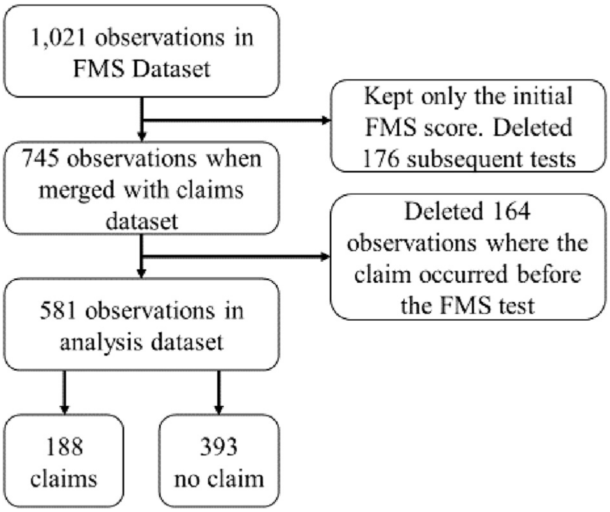

Fig. 1. Study Sample Inclusion and Exclusion Criteria.

The Functional Movement Screen (FMS™) was developed to assess an individual's ability to perform fundamental movements that are necessary to participate in physically active tasks. It is comprised of seven subtests: the deep squat, hurdle step, in-line lunge, shoulder mobility, active leg raise, trunk stability push-up, and rotary stability. Each of these tasks is scored on a scale from zero to three and those scores are summed to a composite score that ranges from zero to twenty-one [5,6]. The underlying theory of the FMS is that an individual needs to be able to properly perform these fundamental movements before they can focus on improving power, strength, and flexibility. The FMS can be used to recognize individuals that may be at risk for physical injury and as a tool to track fitness level and/or injury recovery [5,6].

Previous studies among athletic populations have demonstrated an association between composite FMS score and future injuries [6–12]. For example, among professional football players, a composite score of 14 or less was associated with an injury the following season [12]. This association has also seen among collegiate rowers [8], rugby players [9,11], and high school athletes [7]. While these associations have been shown among athletes, less research has been carried out examining the use of FMS predicting workplace injuries, especially among firefighters and police officers. One study among firefighters found an association between the FMS composite score and work-related injuries [13], whereas another found no association [14]. These studies differed in purpose and methods. Butler et al. [13] aimed to determine if the FMS could be used to determine injury risk among 108 firefighter trainees over the course of their training period, whereas Peate et al. [14] sought to understand if the FMS was associated with previous injuries among 433 active firefighters. In light of the minimal evidence, the purpose of this study was to determine whether the FMS is a useful tool in predicting workplace injuries among a sample of firefighters from the Denver Fire Department (DFD).

2. Materials and methods

2.1. Study population

This sample consisted of firefighters from the DFD who had participated in their wellness initiative. The wellness initiative began in the Fire Academy in 2012 and then expanded to the all the department firehouses in 2014. The wellness initiative was open to all firefighters once it was department wide, but there was an emphasis for participation among recruits. The initiative lasted until the end of 2016. The initiative began in the Fire Academy with new recruits as a matter of proximity. The Wellness Coordinator for the DFD also served as the Strength and Conditioning Coordinator for the Fire Academy, so it was easy to implement with the new recruits. The DFD also wanted to have true baseline scores of the FMS and other tests before the recruits gaining any field experience. It was comprised of five components: (1) conduct a medical exam, (2) conduct a fitness assessment, (3) provide a physical therapist for injury prevention and injury rehabilitation, (4) focus on behavioral health, and (5) collect and analyze data to evaluate the DFD wellness program.

Fig. 1 depicts the flow diagram of how we arrived at our analytical sample. Participants were included in the study if they had at least one composite FMS test score. We limited the data set to only include an individual's initial FMS test. We excluded individuals whose FMS test occurred after a workers' compensation claim since we were interested in the predictive ability of the FMS test on workplace injuries.

2.2. Measures

The main predictor of interest was the FMS composite score which ranges from 0 to 21. The FMS tests were performed by a physical therapist trained in administering this test. For this analysis, the composite score was dichotomized into those that scored 14 or less and those that scored higher than 14. We chose the score of 14 as a cut point based on prior literature [12]. We also looked at the FMS subtest scores, each of which are on a scale from 0 to 3. Those scores were treated as continuous variables.

The main outcome variable was workers' compensation claims. First, we assessed claim vs. no claim, where any workers' compensation claim was given a value of 1 and the absence of a claim was given a value of 0. Second, we focused on claims categorized as overexertion claims, where the claims in that category were given a value of 1 and claims in other categories or the absence of a claim were given a value of 0. Overexertion claims included musculoskeletal injuries such as sprains and strains, which we hypothesized would be more likely to be associated with the FMS than other types of injuries common in firefighters, such as smoke inhalation.

Demographic variables of age, gender, height, weight, body mass index (BMI), resting heart rate, blood pressure, days to maximum medical improvement (MMI), and VO_2max were also assessed. The demographic variables of age and gender were self-reported when individuals went to their wellness check appointments. Height, weight, BMI, resting heart rate, blood pressure, and VO_2max were measured by physical therapists at the wellness check. The VO_2max test was a submaximal treadmill test performed with a heart rate monitor and each test followed the Gerkin Protocol [15].

2.3. Statistical analysis

Descriptive statistics for demographic data were stratified by claim status. Composite and subtest scores for the FMS are displayed by means and standard deviation. Chi-square tests were used to assess the relationship between claim status and the FMS composite score and subtest scores, independently. Logistic regression analysis was used to assess the ability of the FMS score to predict injury after adjusting for age.

Owing to our primary results, we performed secondary ad hoc analyses. To determine if there was an optimal cut point for the FMS score for predicting a claim in our population, we calculated the

Table 1
Demographic characteristics of denver firefighters stratified by claim status

Characteristic	Overall N = 581		Claim N = 188		No claim N = 393	
	Mean (SD)	N (%)	Mean (SD)	N (%)	Mean (SD)	N (%)
Age (years)*	38.4 (9.8)		35.9 (9.2)		39.5 (10.0)	
Gender − male		542 (93.3%)		173 (92.0%)		369 (93.9%)
FMS Score ≤ 14		234 (40.3%)		79 (42.0%)		155 (39.4%)
Height (inches)	70.1 (5.0)		69.6 (2.6)		70.3 (5.6)	
Weight (lbs)	193.8 (30.8)		190.1 (30.3)		195.1 (31.0)	
BMI	27.8 (3.7)		27.4 (3.1)		28.0 (3.8)	
Resting heart rate (bpm)*	69.1 (12.2)		63.9 (10.6)		70.8 (12.3)	
Blood pressure						
Systolic (mmHg)	121.7 (13.5)					
Diastolic(mmHg)	75.6 (9.8)		75.1 (10.9)		75.8 (9.5)	
Time to MMI† (days)	13.5 (0-68.5)		13.5 (0-68.5)		n/a	n/a
VO_2max (mL/kg/min)*	45.0 (4.1)		46.2 (4.0)		44.6 (4.1)	

FMS, Functional Movement Screen.
* Indicates a statistical difference at the 0.05 level for a Student's T-test or Chi-square test between those who had a WC claim and those who did not have a WC claim.
† Due to skewed data, median and inter-quartile range are presented for this variable.

sensitivities and specificities for predicting a claim at several FMS scores previously assessed in the literature [12]. All analyses were carried out using SAS, version 9.4 (Cary, NC) with the type I error rate fixed at 0.05. Results are presented as mean (SD), unless otherwise stated.

2.4. IRB

The Colorado Multiple Institutional Review Board determined this study was not human subjects research.

3. Results

There were 581 individuals who met inclusion criteria. The mean age of our sample was 38.4 (SD: 9.8) years and almost all were male (93.3%) (Table 1). Data on job type was missing for more than half of the participants, but of those who provided this information 109 (40.4%) were firefighters, 70 (25.9%) were officers, 50 (18.5%) were recruits, and 40 (14.8%) were engineers. Nearly a third of them had experienced a workers' compensation claim (32.4%), and the median days to MMI was 13.5 days (IQR: 0 − 68.5 days). Individuals with a claim tended to be younger, have lower blood pressure, and a higher VO_2max score (Table 1).

The distribution of FMS scores in our sample is presented in Fig. 2. The FMS scores in our sample ranged from 2 to 20 (Mean:14.9; SD: 2.3). Overall, 40% of the sample had an initial FMS score of 14 or less. The mean scores for each of the seven subtests were around 2, with the exception of the trunk stability push-up, which was closer to 3. There was no difference in FMS scores by claim status (Table 2).

Similarly, logistic regression results indicated that an FMS score of 14 or less was not associated with any claim [odds ratio (OR) = 1.27, 95% confidence interval (CI): 0.88 − 1.83] nor an overexertion claim (OR = 1.33, 95% CI: 0.81-2.21) after adjusting for age. Age however was associated with claim status, where older firefighters had decreased odds of experiencing any claim (OR = 0.96, 95% CI: 0.94-0.98) and an overexertion claim (OR = 0.97, 95% CI: 0.94-0.99).

The ROC curves depicted in Fig. 3 show that in this sample there is little difference in the occurrence of a claim between those with a composite score of 14 or less and those with a composite score greater than 14. These ROC curves show that using a score of 14 or less will successfully predict a claim about half of the time. No specific cut point was found that optimized both the sensitivity and specificity. Illustratively, for the claim vs. no claim, the sensitivity and specificity were 0.42 and 0.61, respectively, for an FMS score of 14.5 but were 0.59 and 0.42 for an FMS score of 15.5 (Table 3). There were similar patterns for the overexertion claim vs. no claim, other claim group (Table 3).

4. Discussion

In this study population, we found no association between FMS score and workers' compensation claims. Specifically, we saw that firefighters who scored 14 or less on the FMS test were not at a higher risk of incurring any workers' compensation claim nor an overexertion claim. In fact, in accordance with the ROC curves, the FMS was no better at predicting a claim in this population than flipping a coin. We found that in our sample there was no specific cutoff score of the FMS that was a reliable predictor of a claim.

Evidence about the effectiveness of the FMS in predicting injuries among firefighters has been mixed. One study found that in a sample of 108 firefighters who scored 14 or less on their composite FMS score were more likely to be injured over the course of the academy than those that scored higher than 14. Butler et al. [13] found that higher scores for the deep squat and the push-up subtests were associated with injury. The definition of an injury used by Butler et al. [13] (missing three consecutive days of training due to musculoskeletal injury) differed from the definition used in the present study, which could contribute to the conflicting results.

The FMS is not the only fitness measure that has been used as a predictor of an occupational injury among firefighters. VO_2max, a measure of oxygen uptake, has also been studied in relation to firefighter injuries. One study found that firefighters who had lower VO_2max scores were more likely to sustain an injury [4]. Another study found that those who had higher VO_2max scores performed better on a firefighting simulation test [16]. Both studies indicated that firefighters with a better VO_2max had better outcomes, whether that be injury occurrence or performance. Another study that evaluated an intervention among recruits that was comprised strength, cardiovascular, and flexibility training found that those who had received the training had a lower overall injury rate and a lower exercise-related injury rate in their probationary year compared to previous cohorts who had not received the intervention [17], indicating that better overall physical fitness is protective among firefighters. In fact, an evaluation of ways to improve performance and reduce injury risk among firefighters recommended that firefighters should engage in aerobic training, sprint

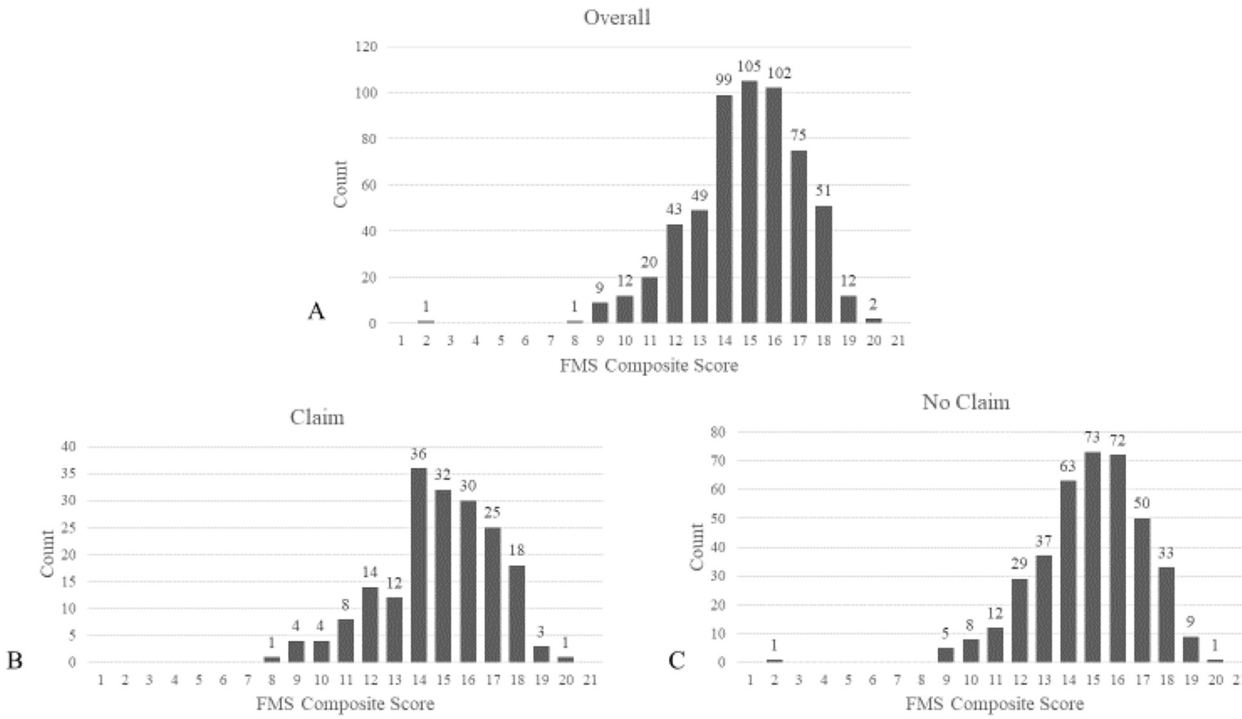

Fig. 2. Distribution of FMS Scores among Denver Firefighters 2015 – 2018. A. Overall FMS Composite Score B. FMS Composite Score among those with a WC claim. C. FMS Composite score among those without a WC claim. FMS, Functional Movement Screen.

interval training, functional training, resistance training, and lifestyle modifications such as a nutrition plan, to prevent injuries [18]. This evaluation shows that the physical fitness of firefighters should encompass more than just one test or aspect of fitness.

Table 2
FMS scores and subscores by claim status

Claim vs. No claim			
FMS score	Overall N = 581	Claim N = 188	No claim N = 393
	Mean (SD)	Mean (SD)	Mean (SD)
Composite Score	14.9 (2.3)	14.8 (2.3)	14.9 (2.2)
Deep squat	2.0 (0.6)	2.0 (0.6)	2.1 (0.6)
Hurdle step	2.0 (0.3)	2.0 (0.3)	2.0 (0.3)
In-line lunge	2.0 (0.7)	2.0 (0.6)	2.0 (0.7)
Shoulder mobility	2.1 (0.7)	2.1 (0.8)	2.1 (0.7)
Active leg raise	2.2 (0.6)	2.3 (0.6)	2.2 (0.6)
Trunk stability push-up	2.7 (0.6)	2.6 (0.6)	2.7 (0.6)
Rotary stability	1.8 (0.4)	1.9 (0.4)	1.8 (0.4)
Overexertion claim vs. No claim/other claim			
	Overall N = 581	Overexertion Claim N = 72	No claim, other caim N = 509
	Mean (SD)	Mean (SD)	Mean (SD)
Composite Score	14.9 (2.3)	14.7 (2.2)	14.9 (2.3)
Deep squat	2.0 (0.6)	2.0 (0.5)	2.1 (0.6)
Hurdle step	2.0 (0.3)	2.0 (0.3)	2.0 (0.3)
In-line lunge	2.0 (0.7)	1.9 (0.7)	2.0 (0.7)
Shoulder mobility	2.1 (0.7)	2.0 (0.7)	2.1 (0.7)
Active leg raise	2.2 (0.6)	2.3 (0.6)	2.2 (0.6)
Trunk stability push-up	2.7 (0.6)	2.7 (0.6)	2.7 (0.7)
Rotary stability	1.8 (0.4)	1.9 (0.4)	1.8 (0.4)

FMS, Functional Movement Screen.

Although the FMS may not be the best predictor of occupational injury among firefighters in our sample, it has been useful in predicting injury among other populations [13,14]. A meta-analysis showed that nine of eleven studies evaluated the use of the FMS for injury prediction. Of those nine, six found that individuals with a score of 14 or less were more likely to sustain an injury [19]. The study populations in this meta-analysis primarily consisted of athletes and military personnel trainees, so it may be more appropriate to use the FMS as an injury predictor in populations performing more athletic based activities, such as playing a sport or training to improve one's physical fitness, given the mechanism of injury may differ for these groups. In the one article among firefighters that demonstrated that the FMS successfully predicted injuries, the injuries occurred while the trainees were still in their training at the fire academy [13]. According to the 2018 United States Firefighter Injury Report, a higher percentage of strain and sprain injuries occur away from the fireground [1]. Similarly, among military personnel, the rate of musculoskeletal injury is higher during training rather than in combat [20]. Musculoskeletal injuries that occur during firefighter training similar to that in Butler et al. may be more comparable with those that occur during military basic training or athletic training [19]. Conversely, many of the injuries in the present study occurred in the field which may contribute to the conflicting findings.

Another potential use of the FMS is as an indicator of pain, which could then be used to predict injury. One study found that while a score of 14 or less was indicative of pain among military personnel, those that reported pain during one of the seven subtests, were more likely to sustain an injury, and that this indicator was stronger than using the composite score [21]. This demonstrates that the FMS can be used beyond just the composite score to predict injuries and that pain could be a better indicator of future injuries than fitness levels. However, we were unable to examine this relationship in our study.

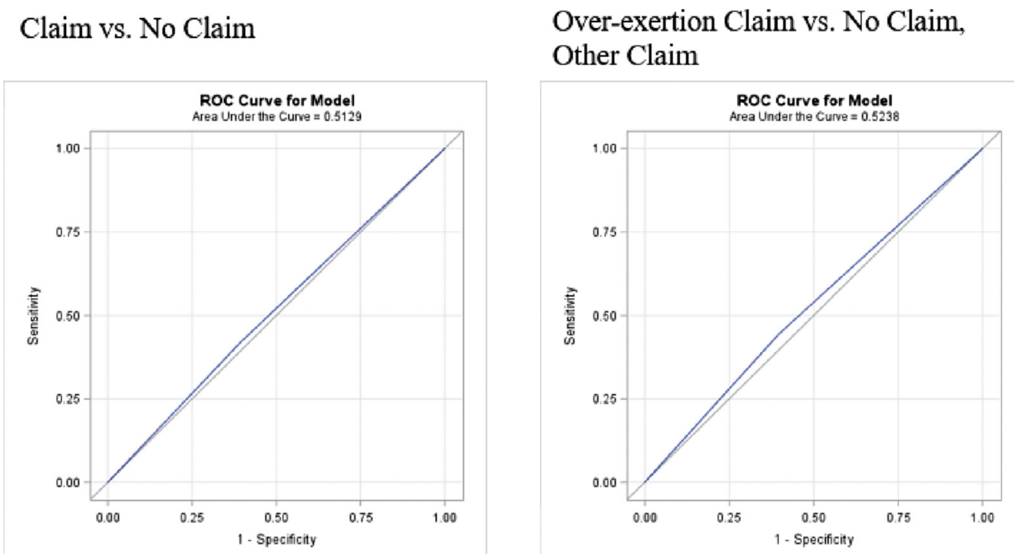

Fig. 3. ROC Curves for FMS Score Predicting Injury among Denver Firefighters. FMS, Functional Movement Screen.

4.1. Strengths and limitations

This study has many strengths. First, this study had a large sample size with multiple years of data, which allowed us to assess the predictive nature of FMS. Second, we had objective data for both the predictor and outcome variables, which reduces the bias introduced to the study. This study also had a few limitations. One is the narrow distribution of the FMS score in this sample. Using workers' compensation claims as the definition of an injury could also be a limitation because injuries often are underreported in workers' compensation claims, which could bias the results toward the null. Although we had some demographic data, we did not have enough power to include those factors in the main analysis. We were not able to adjust for factors such as BMI, which might have been associated with injuries.

Table 3
Sensitivities and specificities at different FMS score cut points

Claim vs. No claim		
FMS score	Sensitivity	Specificity
10.0	0.479	0.964
12.0	0.165	0.8660
13.5	0.229	0.766
14.5	0.420	0.606
15.5	0.590	0.420
16.5	0.750	0.237
17.5	0.883	0.109
18.5	0.978	0.025
20.0	1.000	0.000
Over-exertion claim vs. no claim, other claim		
FMS Score	Sensitivity	Specificity
10.0	0.056	0.963
12.0	0.125	0.849
13.5	0.208	0.764
14.5	0.444	0.603
15.5	0.653	0.426
16.5	0.806	0.248
17.5	0.889	0.112
18.5	0.986	0.026
20.0	1.000	0.000

FMS, Functional Movement Screen.

Physical fitness is an important factor for performance and injury prevention among firefighters. Although the FMS may be a useful measure of fitness amongst firefighters, it did not provide information on which firefighters may be more at risk to sustain a workplace injury in our sample.

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Conflicts of interest

The authors declare they have no conflicts of interest.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.shaw.2020.04.006.

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