# Efficacy of Functional Movement Screening for Predicting Injuries in Coast Guard Cadets

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## Abstract

Knapik, JJ, Cosio-Lima, LM, Reynolds, KL, and Shumway, RS. Efficacy of functional movement screening for predicting injuries in coast guard cadets. *J Strength Cond Res* 29(5): 1157–1162, 2015—Functional movement screening (FMS) examines the ability of individuals to perform highly specific movements with the aim of identifying individuals who have functional limitations or asymmetries. It is assumed that individuals who can more effectively accomplish the required movements have a lower injury risk. This study determined the ability of FMS to predict injuries in the United States Coast Guard (USCG) cadets. Seven hundred seventy male and 275 female USCG freshman cadets were administered the 7 FMS tests before the physically intense 8-week Summer Warfare Annual Basic (SWAB) training. Physical training-related injuries were recorded during SWAB training. Cumulative injury incidence was calculated at various FMS cutpoint scores. The ability of the FMS total score to predict injuries was examined by calculating sensitivity and specificity. Determination of the FMS cutpoint that maximized specificity and sensitivity was determined from the Youden's index (sensitivity + specificity − 1). For men, FMS scores ≤12 were associated with higher injury risk than scores >12; for women, FMS scores ≤15 were associated with higher injury risk than scores >15. The Youden's Index indicated that the optimal FMS cutpoint was ≤11 for men (22% sensitivity, 87% specificity) and ≤14 for women (60% sensitivity, 61% specificity). Functional movement screening demonstrated moderate prognostic accuracy for determining injury risk among female Coast Guard cadets but relatively low accuracy among male cadets. Attempting to predict injury risk based on the FMS test seems to have some limited promise based on the present and past investigations.

**Key Words** sensitivity, specificity, Youden's Index, body mass index

## Introduction

Musculoskeletal injuries continue to be a significant problem for active individuals in both military and civilian environments (11,12,15). In military basic training, about 25% of men and 50% of women will be injured at least once (8,10), and in specific military occupational specialties, injury rates can be even higher (13,20). Currently, individuals working with physically active populations have very limited analytic techniques to determine if an individual might be at risk of injury. Recently, functional movement screening (FMS) has been shown to be a reliable testing procedure (5,16,21) that may assist in filling this gap. Functional movement screening examines the ability of individuals to perform highly specific movements to identify individuals who have functional limitations or asymmetries. It is presumed that individuals who can more effectively control their body to accomplish the required movements have a lower injury risk. Until very recently, there had been few studies in the peer-reviewed literature that had tested the ability of FMS to predict injuries (1,2,9,14,17). With the exception of the study by O'Connor et al. (17), most of these investigations have involved small sample sizes ($n$ = 38–102) and all have demonstrated varying levels of prognostic accuracy.

The purpose of this investigation was to examine the ability of FMS to predict injuries in a unique cohort of male and female Coast Guard cadets engaged in a period of intense physical activity at the United States Coast Guard Academy (USCGA).

## Methods

### Experimental Approach to the Problem and Subjects

This was a prospective cohort investigation examining the association between FMS scores and training-related injuries among new freshmen participating in the Summer Warfare Annual Basic (SWAB) training at the USCGA in New London, Connecticut.

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**TABLE 1.** Physical training program during SWAB training.*

| | Cardiorespiratory training | Muscular strength and muscular endurance training | Flexibility training | Other activities |
|---|---|---|---|---|
| Frequency | 5 times per wk | 2 times per wk | Warm-up and cool down before and after each exercise session<br>Dynamic stretching daily | 4–5 times per wk |
| Intensity | 60–90% HRR | 8–12 RM | Slight discomfort but no pain | 60–90% HRR |
| Duration | 60 min or more | Less than 60 min | 10–15 s per stretch for warm-up and cool down<br>30 s per stretch for improvement of flexibility | Up to 60 min |
| Activities | Running, marching with backpack on campus | Free weights | Static passive, PNF | Recreation: all sports (duty and off duty) |
| | Sprint intervals of 100 and 220 yards, 3 times per week, 4–10 repetitions each | Resistance machines | Dynamic stretches | |
| | Bike interval training of 30 and 60 s, 2 times per wk, 4–10 repetitions | Sit-ups | Knee hug | |
| | Sled pulls of 15 s, 2 times per wk, 4–10 repetitions | Pull-ups | Quad stretch | |
| | | Push-ups | Butt kickers | |
| | | Body weight squats | Spider man stretch | |
| | | Core planks | Inch worms | |
| | | Sea turtles | Shoulder 90/90 stretch | |
| | | Medicine ball whole body exercises | Lateral lunge stretch | |
| | | | Hip flexor/quad stretch | |
| | | | 2 inch runs | |
| | | | Ankle band/monster walks/lateral squat | |

*SWAB = Summer Warfare Annual Basic; HHR = heart rate reserve; RM = repetition maximum; PNF = proprioceptive neuromuscular facilitation.

#### Subjects

In addition to academic and ethical requirements, entry into the USCGA requires athletic accomplishment and passing a physical fitness test consisting of push-ups, sit-ups, and a 1.5 mile run. Generally, 6% of all applicants are accepted into the academy. Over a 4-year period, classes of incoming cadets (approximately 1,200 cadets total) were briefed on the purposes and risks of the investigation. Of those briefed, 770 male and 275 female cadets consented to volunteer. Age range for men were 18-22 years and for women were 18-21 years. The study started with the first class briefing in July 2004, and the last class completed SWAB training in September 2007. Institutional approval for the study was granted by the USCGA.

#### Procedures

Functional movement screening involves 7 movement tests that subjects must perform using highly specific movement patterns (16,19). Each test is scored on a 4-level ordinal scale (0–3). The 7 scores (1 score for each test) are added together for a final score that can vary from 0 to 21. In this study, FMS tests were administered to cadets in a single session before SWAB training in accordance with the standard FMS criteria (19). The testing was conducted by research staff members including a physical therapist certified in FMS testing who monitored all examinations. Each tester was trained only on the test they were administering. Cadets had a FMS scoring sheet, which they carried and which was collected at the end of testing for data entry. Cadets performed the tests in t-shirt, shorts, socks, and sneakers. Testing was conducted throughout the day as part of the cadet training schedule.

Data on date of birth and gender were obtained from the Coast Guard Academy Data Tracking Computer System (ACADIS) at the beginning of each year. Age was calculated from date of birth to the start of cadet training. A Cadet

**Table 2.** Association between FMS scores and injury risk at various FMS cutpoints.*

| FMS score | Men: Injured (n) | Men: Not injured (n) | Men: Injured (%) | Men: RR (95% CI) | Men: *p* | Women: Injured (n) | Women: Not injured (n) | Women: Injured (%) | Women: RR (95% CI) | Women: *p* |
|---|---|---|---|---|---|---|---|---|---|---|
| ≤9 | 23 | 58 | 28.4 | 1.63 (1.11–2.39) | 0.02 | 16 | 22 | 42.1 | 1.91 (1.23–2.98) | <0.01 |
| ≥10 | 120 | 568 | 17.4 | | | 52 | 184 | 22.0 | | |
| ≤10 | 28 | 67 | 29.5 | 1.73 (1.22–2.46) | <0.01 | 16 | 24 | 40.0 | 1.81 (1.15–2.83) | 0.02 |
| ≥11 | 115 | 560 | 17.0 | | | 52 | 183 | 22.1 | | |
| ≤11 | 31 | 80 | 27.9 | 1.64 (1.17–2.32) | <0.01 | 17 | 22 | 38.6 | 1.75 (1.12–2.73) | 0.02 |
| ≥12 | 112 | 547 | 17.0 | | | 51 | 180 | 22.1 | | |
| ≤12 | 38 | 121 | 23.9 | 1.39 (1.00–1.93) | 0.05 | 20 | 35 | 36.4 | 1.66 (1.08–2.56) | 0.03 |
| ≥13 | 105 | 506 | 17.2 | | | 48 | 172 | 21.8 | | |
| ≤13 | 48 | 207 | 18.8 | 1.02 (0.75–1.40) | 0.90 | 30 | 53 | 36.1 | 1.83 (1.22–2.73) | <0.01 |
| ≥14 | 95 | 420 | 18.4 | | | 38 | 154 | 19.8 | | |
| ≤14 | 79 | 321 | 19.8 | 1.14 (0.85–1.54) | 0.38 | 41 | 80 | 33.9 | 1.93 (1.27–2.95) | <0.01 |
| ≥15 | 64 | 306 | 17.3 | | | 27 | 127 | 17.5 | | |
| ≤15 | 109 | 462 | 19.1 | 1.12 (0.79–1.59) | 0.53 | 51 | 115 | 30.7 | 1.97 (1.20–3.23) | <0.01 |
| ≥16 | 34 | 165 | 17.1 | | | 17 | 92 | 15.6 | | |
| ≤16 | 131 | 549 | 19.3 | 1.45 (0.84–2.50) | 0.17 | 57 | 168 | 25.3 | 1.15 (0.65–2.03) | 0.62 |
| ≥17 | 12 | 78 | 13.3 | | | 11 | 39 | 22.0 | | |
| ≤17 | 136 | 601 | 18.5 | 0.83 (0.40–1.71) | 0.62 | 63 | 189 | 25.0 | 1.33 (0.47–3.78) | 0.57 |
| ≥18 | 6 | 21 | 22.2 | | | 3 | 13 | 18.8 | | |
| ≤18 | 142 | 622 | 18.6 | 1.12 (0.19–6.72) | 0.90 | 66 | 202 | 24.6 | 0.86 (0.26–2.83) | 0.81 |
| ≥19 | 1 | 5 | 16.7 | | | 2 | 5 | 28.6 | | |

*FMS = functional movement screening; RR = risk ratio; CI = confidence interval.

Battalion Trainer measured body weight and height. Height was measured to the nearest centimeter using a stadiometer. Weight was measured using a SECA platform scale (Chino, CA, USA). Body mass index (BMI) was calculated by dividing the subject's weight by the height squared (kilogram per square meter).

A few days after completing the FMS and physical characteristic measurements, the cadets began SWAB training. Summer Warfare Annual Basic training was an 8-week course designed to assist new Coast Guard cadets in acquiring specific proficiencies and knowledge and transition into the lifestyle of a U.S. Coast Guard officer. The process included physical fitness training, seamanship, swimming, academics, and the development of critical military skills. Table 1 shows the physical training program in which all cadets participated.

**Table 3.** Sensitivity, specificity and Youden's index for FMS scores.*

| FMS cutpoint | Men: Sensitivity (%) | Men: Specificity (%) | Men: Youden's Index | Women: Sensitivity (%) | Women: Specificity (%) | Women: Youden's Index |
|---|---|---|---|---|---|---|
| ≤9 and ≥10 | 16.1 | 90.7 | 0.068 | 23.5 | 89.3 | 0.128 |
| ≤10 and ≥11 | 19.6 | 89.3 | 0.059 | 23.5 | 88.4 | 0.119 |
| ≤11 and ≥12 | 21.7 | 87.2 | 0.089 | 25.0 | 87.0 | 0.120 |
| ≤12 and ≥13 | 26.6 | 80.7 | 0.073 | 29.4 | 83.1 | 0.124 |
| ≤13 and ≥14 | 33.6 | 67.0 | 0.006 | 44.1 | 74.4 | 0.185 |
| ≤14 and ≥15 | 55.2 | 48.8 | 0.040 | 60.3 | 61.4 | 0.217 |
| ≤15 and ≥16 | 76.2 | 26.3 | 0.025 | 75.0 | 44.4 | 0.194 |
| ≤16 and ≥17 | 91.6 | 12.4 | 0.040 | 83.8 | 18.8 | 0.026 |
| ≤17 and ≥18 | 95.8 | 03.4 | −0.008 | 95.5 | 06.4 | 0.019 |
| ≤18 and ≥19 | 99.3 | 00.8 | 0.001 | 97.1 | 02.4 | −0.005 |

*FMS = functional movement screening.

| | Injured | Not Injured |
|---|---|---|
| Low FMS Score | Cell a<br>True Positive | Cell b<br>False Positive |
| High FMS Score | Cell c<br>False Negative | Cell d<br>True Negative |

**Figure 1.** Two by two contingency table showing classifications outcomes for injury and functional movement screening scores.

Emphasis was on cardiorespiratory training (running and marching), resistance/muscle endurance training, and flexibility. Other military-related physical training activities included obstacle courses, rope course challenges, and a 7-day sailing cruise on the USCGC Eagle, one of only 2 active commissioned sailing vessels in the U.S. military service.

A physical therapist who was part of the research staff diagnosed SWAB training-related injuries and recorded the information in the cadets' medical records. At the end of each SWAB training cycle, a physical therapist and other health care providers who were not part of the study screened the medical records and recorded injuries related to the SWAB physical training. A training injury was defined as any physical damage to the body that resulted in a clinic visit, and that was suspected to have been caused by SWAB physical training (i.e., unit fitness training, operational training, or recreational sports conditioning).

#### Statistical Analyses

Statistical Package for the Social Sciences (SPSS, version 18; SPSS, Inc., Chicago, IL, USA) was used for the statistical analyses. Descriptive statistics were calculated for the physical characteristics and total FMS scores. Difference in FMS scores between men and women was examined with an independent sample *t*-test. Cumulative injury incidence was calculated as the Σ of cadets with one or more injuries divided by Σ of all cadets times 100 (injured %). Receiver operating characteristic curves were calculated by paring FMS scores with injury incidence. Chi-square statistics were used to evaluate differences in injury risk among different FMS cutpoints, and a risk ratio (RR) and 95% confidence interval (95% CI) were calculated by comparing those above and below each cutpoint. Sensitivity and specificity were calculated from 2 × 2 contingency tables (4,6). The Youden's Index (sensitivity + specificity − 1) was used to determine the FMS total score cutpoint that optimized sensitivity and specificity (22).

**Table 4.** Studies examining association between injury risk and FMS cutpoint ≤14.*

| Study | Subjects | Injury definition | FMS score (mean ± *SD*) | Injury, 14 ≤ RR > 14 (95% CI) | Sensitivity (%) | Specificity (%) |
|---|---|---|---|---|---|---|
| Kiesel et al. (9) | 46 male professional football players | Player placed on injury reserve list and time loss of ≥3 wk | 16.9 ± 3.0 | 4.2 (1.8–9.7) | 53.9 | 90.9 |
| Chorba et al. (2) | 38 female collegiate soccer, volleyball and basketball players | Sport-related musculoskeletal injury seen by medical care provider | 14.3 ± 1.8 | 1.9 (1.0–3.6) | 57.9 | 73.7 |
| O'Conner et al. (17) | 874 male marine corps officer candidates | Any musculoskeletal or dermatological injury | 16.6 ± 1.7 | 2.0 (1.3–3.1) | 45.2 | 78.2 |
| Butler et al. (1) | 108 firefighters engaged in training at academy (gender not specified) | Episode resulting in 3 consecutive days of missed training due to musculoskeletal pain | Not reported | Not reported | 83.5 | 62.1 |
| This study | 770 male Coast Guard cadets | Any physical training-related injury | 14.5 ± 1.9 | 1.1 (0.9–1.5) | 55.2 | 48.8 |
| | 275 female Coast Guard cadets | Any physical training-related injury | 15.1 ± 1.9 | 1.9 (1.3–3.0) | 60.3 | 61.4 |

*FMS = functional movement screening; RR = risk ratio; CI = confidence interval.

## Results

The mean ± *SD* age, height, weight, and BMI of the male cadets were 18.1 ± 0.7 years, 179 ± 7 cm, 77 ± 12 kg, and 23.6 ± 3.2 $kg \cdot m^{-2}$, respectively. For the female cadets, these values were 17.9 ± 0.7 years, 166 ± 7 cm, 63 ± 8 kg, and 22.6 ± 2.7 $kg \cdot m^{-2}$, respectively. The mean ± *SD* of total FMS scores for men was 14.5 ± 1.9 and for women was 15.1 ± 1.9 ($p = 0.02$). Cumulative injury incidence was 18.6% for men and 24.7% for women (RR [women:men], 1.33; 95% CI, 1.03–1.72; $p = 0.03$).

Receiver operating characteristic curves yielded areas under the curve of 0.53 for men and 0.59 for women. Table 2 shows the association between FMS scores and injury risk for various FMS cutpoints. For men, FMS scores ≤12 were associated with higher injury risk than scores >12 and for women, FMS scores ≤15 were associated with higher injury risk than scores >15. Table 3 shows the sensitivity, specificity, and Youden's Index at various FMS cutpoints. The Youden's Index indicated that the FMS cutpoints that optimized specificity and specificity were ≤11 for men and ≤14 for women. At these optimal cutpoints, injury risk among both men and women was greater for those with lower FMS total scores (Figure 1; Table 4 and their Table 5).

## Discussion

This investigation demonstrated that during SWAB training, higher injury risk was associated with FMS scores ≤12 for male Coast Guard cadets and ≤15 for female Coast Guard Cadets. The FMS cutpoint that maximized the ability to detect those at high injury risk (sensitivity) and ability to detect those not at risk (specificity) were ≤11 for men and ≤14 for women, generally in consonance with the overall injury risk. However, the prognostic accuracy at the optimal FMS cutpoint among men (≤11) was relatively low with only 22% of injured men correctly predicted. The prognostic accuracy at the optimal cutpoint among women (≤14) was somewhat better with 60% of women correctly classified as at risk of injury.

At higher FMS cutoff scores, sensitivity systematically increased and specificity decreased as shown in Table 3. Figure 1 shows a 2 × 2 contingency table with all possible classification outcomes for injuries and FMS scores. In the case of sensitivity, progressively higher cutoff scores resulted in progressively more injured individuals placed in the true-positive cell (cell a) and fewer in false-negative cell (cell c): more injured cadets were correctly classified, thus increasing sensitivity. By the cutpoint of ≤18, virtually all injured individuals were in the true-positive cell (cell a). In the case of specificity, progressively higher cutoff scores resulted in progressively more individuals placed in the false-positive cell (cell b) and fewer in the true-negative cell (cell d): fewer of the uninjured cadets were correctly classified in the true-negative cell and this decreased specificity. The Youden's Index provided a simple calculation that objectively identified the cutpoint that provided the optimal combination of specificity and specificity for these data.

A previous study (9) indicated that FMS scores ≤14 had optimal ability to predict injury risk, and other studies have used this as a cutpoint for their investigations (1,2,17). Table 4 show a summary of these studies along with similar information from this investigation. Types of participants and injury definitions in these studies differed considerably. Participants included athletes (2,9), Marine Corps officer candidates (17), firefighters (1), and Coast Guard cadets. Injury definitions included physical damage to the body of virtually any type (2,17) and physical damage that resulted in lost training time (1,9). Average FMS scores in this study were similar to that of Chorba et al. (2) but generally lower than other investigations that reported this variable (9,17). Among studies reporting injury risk, this risk was elevated in all groups with FMS scores ≤14 with the exception of the male cadets in this study. While sensitivity in this study was similar to most other investigations (2,9,17), specificity was considerably lower. Not included in Table 3 was the study by Letafatkar et al. (14) who reported that a FMS score of ≤17 was optimal for injury prediction in their group of male and female athletes (basketball, soccer, handball) with a sensitivity of 65% and specificity of 78%. However, their data were difficult to interpret because their 2 × 2 table (Table 5) indicated only modestly elevated injury risk among those below the FMS score of 17 (17 ≤ RR > 17, 1.29; 95% CI, 0.81–2.05, secondary data analysis).

## Practical Applications

In this study, FMS demonstrated moderate prognostic accuracy for injury risk among female Coast Guard cadets but relatively low accuracy for predicting injuries in male cadets. Attempting to identify injury risk based on the FMS test seems to have some limited promise based on the present and past investigations and investigations should be conducted with other populations using more standardized reporting of results. Future studies should describe, at a minimum, injury risk, specificity, sensitivity, and the Youden's Index for a range of cutpoints to allow more accurate comparisons across investigations. Previous studies (1,2,9,14,17) have only reported specificity and sensitivity at a single FMS score, and a wider range of scores should be described with the statistics mentioned above. Studies should also consider other functional movement tests involving balancing activities (e.g., Star Excursion Test, Y-Balance Test [3]) because scores from many of these have been shown to be associated with injuries (7,18).

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