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original research

The Interrelationship of Common Clinical Movement Screens: Establishing Population-Specific Norms in a Large Cohort of Military Applicants

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Context: Musculoskeletal injuries (MSK-Is) are a leading cause of missed duty time and morbidity in the military. Modifiable risk factors for MSK-Is, such as inadequate core stability, poor movement patterns, and dynamic balance deficits, have not been identified in military applicants on entering service.

Objective: To establish normative functional movement data using a series of screens in military applicants entering basic training and explore relationships among several movement tests.

Design: Cross-sectional study.

Setting: Military Entrance Processing Station.

Patients or Other Participants: A total of 1714 (1434 male, 280 female) military applicants entering the US Army (n = 546), Navy (n = 414), Air Force (n = 229), or Marine Corps (n = 525).

Intervention(s): We conducted the Functional Movement Screen (FMS), Y-Balance Test (YBT), overhead squat (OHS), and Landing Error Scoring System (LESS). Movements were assessed using the scoring convention for each screen.

Main Outcome Measure(s): The FMS, YBT, OHS, and LESS scores and associations among the movement screens as well as clinical meaningfulness.

Results: A total of 1037 of the 1714 enrolled applicants were screened on the day they left for basic training. Normative means for this population were established: FMS = 14.7 ± 1.8, YBT anterior-reach difference = 3.1 ± 3.0 cm, mean YBT composite differences = 8.0 ± 6.8 cm, mean YBT composite percentage = 90.9% ± 8.3%, OHS errors = 5.0 ± 2.8, and LESS score = 5.7 ± 2.1. Backward regression results revealed that the YBT composite percentage was related to the FMS and OHS scores in males and to the FMS and LESS results in females. However, clinically meaningful relationships between the tests varied for both males and females.

Conclusions: Sex-normative values for the FMS, YBT, OHS, and LESS screens were established for US military applicants, and some of the assessments overlapped. Overall, males performed better on the OHS and LESS and achieved a greater YBT composite percentage than females. The regression results revealed movement screen performance relationships that varied by sex and clinical meaningfulness. In future studies, we will determine if performance on any of the screens is associated with MSK-Is in basic trainees.

Key Words: basic training, musculoskeletal injury, functional, injury risk screening

Key Points

- We established sex-normative values for the Functional Movement Screen, Y-Balance Test, overhead squat, and Landing Error Scoring System in applicants entering basic training in the US Army, Navy, Air Force, or Marine Corps and observed some overlap in the assessments.
- Males performed better on the overhead squat and Landing Error Scoring System and had a greater Y-Balance Test composite percentage than females.
- Movement screen performance relationships varied by sex and clinical meaningfulness.

Musculoskeletal injuries (MSK-Is) are a main cause of missed duty time and morbidity across the armed services.[1] In basic training, MSK-Is are a leading cause of attrition and a substantial financial burden. Approximately 25% of male and 50% of female recruits will sustain 1 or more MSK-Is before they graduate, with almost 20% of those injured receiving disability-related medical discharges.[2–5] These injuries in basic training compromise military readiness because either they delay soldier placement into critical military specialties or, worse, the injured soldiers must leave the military due to the physical inability to perform their required military tasks and jobs. The cost to recruit, screen, and initially train a single applicant is approximately $75 000.[6] Training delays not only increase recruitment costs but also increase the health care costs to treat these injuries. Whereas numerous authors[2,3,5] have identified risk factors for MSK-Is in basic training, attrition and MSK-I morbidity rates remain unacceptably high.

Several investigators[7–9] have identified lower levels of physical fitness, cigarette smoking, a history of injury, and anatomic factors at military entry as risk factors for MSK-Is in basic training populations. However, attempts to reduce the effects of these risk factors have focused on items that take a considerable time to modify or account for a low percentage of the overall risk for MSK-Is (eg, footwear,

Table 1. Total Number of Enrolled Participants by Branch of Service and Sex

Branch of Service	Total Enrollees No. (%)	Sex of Enrollees: Males No. (%)	Females No. (%)
Army	546 (32)	449 (82)	97 (18)
Navy	414 (24)	324 (78)	90 (22)
Air Force	229 (13)	192 (84)	37 (16)
Marine Corps	525 (31)	469 (89)	56 (11)
Total	1714 (100)	1434 (84)	280 (16)

Table 2. Participant Demographics

Characteristic	Sex, Mean ± SD: Males (n = 1434)	Females (n = 280)
Age, y	20.8 ± 3.0	20.9 ± 3.2
Height, cm	176.4 ± 7.2	162.7 ± 6.9
Mass, kg	75.7 ± 11.4	60.5 ± 7.9
Body mass index	24.3 ± 3.1	22.9 ± 2.5

baseline physical fitness, total run mileage, segregating by running ability).[10–12] In addition, most injury-reduction attempts in the basic trainee population have been conducted after applicants have been accepted into service to begin rigorous training regimes. Only Niebuhr et al[13] investigated injury risk factors before basic training. They used a 5-minute step test to assess cardiovascular fitness and motivation and reported that performance on the Assessment of Recruit Motivation and Strength test was related to the risk of MSK-Is during the first 90 days of service[14] and attrition within the first 180 days of service.[13]

Whereas the results from the Assessment of Recruit Motivation and Strength study are promising, we are unaware of published research that addresses other modifiable risk factors in basic trainees, such as inadequate core stability, poor movement patterns, and dynamic balance deficits, which have been found to predict MSK-Is in athletic and military populations.[15–17] Military applicants currently undergo several examinations at a Military Entrance Processing Station (MEPS) before being deemed physically fit to begin basic training. The examinations include a physical history and several orthopaedic tests to identify preexisting musculoskeletal conditions that may preclude applicants from entering the military but do not specifically assess the modifiable risk factors previously tied to increased injury risk, including functional movement, balance, and cardiovascular fitness. These deficits are easily and reliably identified by several easy-to-perform clinical movement screens; therefore, if these screens predict MSK-Is during basic training, preventive measures could be implemented before training begins, and the burden of MSK-Is could ultimately be decreased.

The Military Entrance Processing Screen to Assess Risk of Training (MEPSTART) was developed to address this gap in the literature. It was initiated to identify these modifiable MSK-I risk factors using clinical movement screening tools and subsequently following participants through basic training to track outcomes in a large cohort of military applicants; tracking started the day they shipped to basic training. Therefore, the purpose of our study was to establish normative functional movement data for military applicants entering basic training in the US Army, Navy, Air Force, and Marine Corps. In addition, we explored the relationships among the movement tests and examined how these relationships, if different and meaningful, could affect our ultimate goal of developing a sensitive and specific test battery for predicting the risk for MSK-Is in basic trainees. This study is the first in a series to explore MEPSTART outcome measures, including analyses of movement test scoring criteria, basic-training injury outcomes, and the ability of MEPSTART to predict injury during basic training.

METHODS

Study Design and Participants

The MEPSTART is a prospective cohort study. Applicants cleared to begin basic training between February 2013 and December 2014 in an active-duty component of the US Army, Navy, Air Force, and Marine Corps were recruited at the Baltimore, Maryland, MEPS on the day of entry into military service. Table 1 presents the sex and service distribution of participants who volunteered: a total of 1714 (1434 males, 280 females) entering the US Army (n = 546), Navy (n = 414), Air Force (n = 229), or Marine Corps (n = 525). The baseline demographics for this cohort are provided in Table 2. Given circumstances beyond our control, 677 enrolled participants were unavailable to report for movement screening. Therefore, we present our findings from a total of 1037 participants who were at least partially screened on 1 or more tests. Civilian study staff (P.L. and a nonauthor) thoroughly briefed potential participants about the project, including benefits and risks. All participants provided written informed consent and signed Health Insurance Portability and Accountability Act authorization forms to permit our use of protected health information for research. The study was approved by the US Military Entrance Processing Command and the Institutional Review Board of the Uniformed Services University of the Health Sciences.

Procedures

After completing the final medical examination required for entry into service, participants reported to a separate room within the MEPS facility and completed a brief behavioral and MSK-I history questionnaire before performing MEPSTART functional movement testing procedures. Several testers (P.L. and 2 nonauthors) processed applicants through the test battery in a timely manner. We chose each clinical movement screen based on a thorough literature review for risk-factor identification, recommendations from subject-matter experts, and ease of implementation in a fast-moving environment. All testers received formalized training in the movement screens and were Functional Movement Screen (FMS) certified.

Functional Movement Screen. The FMS comprises 7 tests (shoulder mobility, deep squat, in-line lunge, hurdle step, push-up, supine active straight-leg raise, and rotary stability) used to assess functional movement patterns.[18,19] Each component is scored on a scale from 0 to 3 points

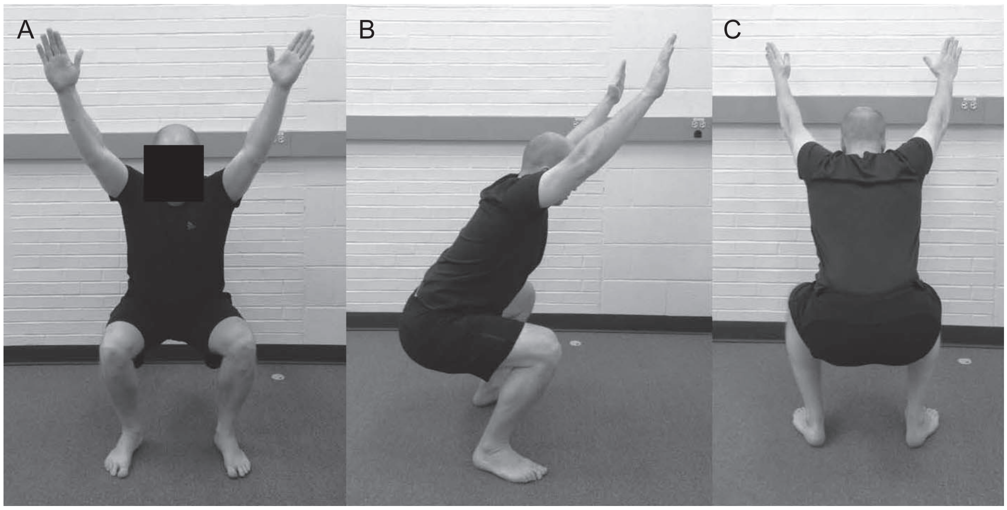

Figure. Overhead squat from A, anterior, B, lateral, and C, posterior views.

based on movement quality and the presence of pain. *Unrestricted and pain-free completion* of each test receives a score of 3, and *pain with movement* is scored 0. Total scores for all components range from 0 to 21 points. Detailed methods of FMS testing have been described.[20]

Y-Balance Test. The Y-Balance Test (YBT) is a dynamic balance assessment requiring participants to maintain a single-legged stance while using the opposite foot to push a reach indicator box as far as possible. Lower extremity length of participants was measured in supine position from the anterior-superior iliac spine to the tip of the medial malleolus. Oral instructions were given, and participants practiced 4 trials on each limb in 3 directions (anterior, posteromedial [PM], and posterolateral [PL] relative to the stance limb) to minimize the influence of a learning effect. Recorded trials were completed after a brief rest, with the maximum of the 3 trials in each direction and for each limb used for analyses. Testing procedures followed those described by Plisky et al.[21] For this study, the 3 YBT components shown to predict injury were used: anterior-reach difference (YBT-Adiff), composite difference (YBT-Comp diff), and normalized composite percentage (YBT-Comp%).[16,22]

Overhead Squat. The overhead squat (OHS) test is a new movement assessment that has been adapted from the methods recommended by the National Academy of Sports Medicine[23] and identifies movement compensations at the shoulder, trunk, hip, knee, and ankle during performance of a double-legged squat (Figure). Different from the FMS deep squat, participants are instructed to slowly squat down as deep as they can (or to roughly the height of a chair) 3 times while barefoot with their upper extremities extended straight and palms facing forward. Movement compensations are scored on a 3-point ordinal scale (0 to 2) from the anterior and posterior perspectives and on a 2-point ordinal scale (0 to 1) from a lateral viewpoint. Total scores range from 0 to 14, with 0 indicating *completion of the OHS without any movement compensation*.

Landing Error Scoring System. The Landing Error Scoring System (LESS) is a reliable clinical movement analysis tool that has been validated against jump-landing biomechanics and has good interrater (intraclass correlation coefficient [2,1] = 0.84, SEM = 0.71) and intrarater (intraclass correlation coefficient [2,1] = 0.91, SEM = 0.42) reliability.[24] The jump-landing task was completed according to the procedures of Padua et al.[24] However, given that the LESS has a suspected ceiling effect,[25] we added several error items, which expanded the LESS from 17 to 22 total items. The average LESS score from the 3 trials was used for analysis.

Statistical Analysis

Descriptive statistics, including means and standard deviations, were calculated for all MEPSTART components. For each subsample, separate sex-specific, hierarchical, stepwise, backward regression analyses were conducted for each MEPSTART screening test using data from each set of movement screens. The YBT calculations were treated as independent of one another, so potential explanatory variables included the FMS composite score, YBT-Adiff, YBT-Comp diff, YBT-Comp%, and OHS and LESS scores. A P value of .05 or less was required to enter the model, and a P value of .06 or greater was grounds for removal. Multicollinearity among variables was assessed by checking variance inflation factors greater than 10. Because of the large number of explanatory variables being evaluated, we first examined Pearson product moment correlations by sex and considered only those with P values of .05 or less for entry into the sex-specific regression models. Finally, to determine the clinical relevance and efficacy of the regression findings, Cohen f^2 effect sizes were calculated and categorized as *large* ($\geq$0.35), *medium* (0.15–0.34), or *small* (0.02–0.14). Given the exploratory nature of the study, effect sizes equal to or greater than 0.15 were considered clinically relevant.[26] All statistical analyses were performed using SPSS software (version 22.0; IBM Corp, Armonk, NY).

RESULTS

Descriptive Analyses

The mean scores of males and females for all MEPSTART components are shown in Table 3. Males had greater YBT-Comp% ($t_{984} = 3.6$, $P < .001$) and fewer

Table 3. Military Entrance Processing Screen to Assess Risk of Training Component Scores

Movement Screen	Mean ± SD (n) Overall	Males	Females
Functional Movement Screen composite score	14.7 ± 1.8 (933)	14.8 ± 1.8 (786)	14.4 ± 1.8 (147)
Y-Balance Test anterior-reach difference, cm	3.1 ± 3.0 (1001)	3.1 ± 3.0 (849)	3.0 ± 2.5 (152)
Y-Balance Test composite percentage, % leg length[a]	90.9 ± 8.3 (984)	91.3 ± 8.3 (837)	88.7 ± 7.9 (147)
Y-Balance Test composite difference, cm	8.0 ± 6.8 (1000)	8.1 ± 7.0 (849)	7.4 ± 5.9 (151)
Overhead squat score, errors[a]	5.0 ± 2.8 (958)	4.9 ± 2.8 (811)	5.9 ± 2.7 (147)
Landing Error Scoring System score, errors[a]	5.7 ± 2.1 (521)	5.5 ± 2.1 (431)	6.5 ± 1.8 (90)

[a] Indicates difference between males and females ($P < .05$).

OHS ($t_{958} = -3.8$, $P < .001$) and LESS ($t_{397} = -3.8$, $P < .001$) errors than females.

Correlation Analyses

The Pearson product moment correlations among all movement tests for males and females, respectively, are presented in Tables 4 and 5. These correlations revealed that FMS scores were related to YBT-Comp%, OHS score, and LESS score in males and to YBT-Comp%, YBT-Comp diff, and OHS score in females.

Regression Analyses

The results of the regression analyses are provided in Tables 6 and 7 for males and females, respectively, with each column representing the final model for the test of interest. For the FMS scores of males, only YBT-Comp% and OHS score were retained in the final regression model (adjusted $R^2 = 0.26$, $P < .001$; Table 6, column 1) and explained 26% of the variance in FMS scores. The large effect size (Cohen $f^2 = 0.35$) indicated that this was clinically meaningful, with better performance on the FMS associated with greater YBT-Comp% and fewer OHS errors. For women, only YBT-Comp% was retained in the final regression model for FMS scores, with a medium effect size (adjusted $R^2 = 0.17$, $P < .001$; Table 7, column 1). Better performance on the FMS was associated with a greater YBT-Comp%.

For the YBT-Adiff final regression model, both YBT-Comp diff and OHS scores (both $P < .001$) were retained for males but explained only 8% of the variance in scores (Table 6, column 2). Moreover, the effect size did not reach the clinically meaningful threshold (adjusted $R^2 = 0.08$, $P < .001$, Cohen $f^2 = 0.09$). For females, YBT-Comp diff was the only variable related to YBT-Adiff, but it explained only 3% of the variance in scores and was not clinically relevant (Table 7, column 2).

Both the FMS and OHS score were retained in the final regression model for YBT-Comp% for males (Table 6, column 3). Greater YBT-Comp% was associated with clinically relevant higher FMS and lower OHS scores. For females, both the FMS and LESS were retained in the final model, with a medium effect size (Cohen $f^2 = 0.33$; Table 7, column 3). A higher YBT-Comp% was associated with better FMS and LESS scores.

When the variable YBT-Comp diff was evaluated, only YBT-Adiff was retained in the final model for males, and only 10% of the variance in scores was explained (Table 6, column 4). The Cohen f^2 effect size was also not clinically meaningful. The final model for females included both the YBT-Adiff and YBT-Comp% (Table 7, column 4). However, only 9% of the variance was explained, and the effect size was low.

For the OHS for males, the final regression model included the FMS, YBT-Comp%, and the LESS score, but together these accounted for only 23% of the variance in OHS scores (Table 6, column 5). A lower OHS score was associated with higher FMS scores, greater YBT-Comp%, and lower (better) LESS scores. For females, only the YBT-Comp% was retained, but it was not clinically relevant according to the effect size (Cohen $f^2 = 0.06$; Table 7, column 5).

Finally, the OHS was the only test retained in the final regression model for the LESS in males, but the explained variance and effect size were low (Table 6, column 6). For females, YBT-Comp% was retained in the final model but was not clinically relevant (Table 7, column 6).

Table 4. Pearson Correlations (*r* Values) Between the Various Movement Tests for Males

Movement Screen	Functional Movement Screen Composite Score	Y-Balance Test: Anterior-Reach Right–Left Difference	Y-Balance Test: Composite Percentage	Y-Balance Test: Composite Difference	Overhead Squat Score	Landing Error Scoring System Score
Functional Movement Screen composite score		Not correlated[a]	0.40 ($P < .001$)	Not correlated[a]	−0.43 ($P < .001$)	−0.13 ($P = .03$)
Anterior-reach difference			Not correlated[a]	0.32 ($P < .001$)	0.08 ($P = .03$)	Not correlated[a]
Y-Balance Test composite percentage				Not correlated[a]	−0.32 ($P < .001$)	Not correlated[a]
Y-Balance Test composite difference					Not correlated[a]	Not correlated[a]
Overhead squat score						0.19 ($P = .001$)
Landing Error Scoring System score						

[a] $P > .05$.

Table 5. Pearson Correlations (r Values) Between the Various Movement Tests for Females

Movement Screen	Functional Movement Screen Composite Score	Y-Balance Test: Anterior-Reach Right–Left Difference	Y-Balance Test: Composite Percentage	Y-Balance Test: Composite Difference	Overhead Squat Score	Landing Error Scoring System Score
Functional Movement Screen composite score		Not correlated[a]	0.43 ($P < .001$)	−0.18 ($P = .03$)	−0.27 ($P = .002$)	Not correlated[a]
Anterior-reach difference			Not correlated[a]	0.20 ($P = .01$)	Not correlated[a]	Not correlated[a]
Y-Balance Test composite percentage				−0.18 ($P = .03$)	−0.25 ($P = .002$)	−0.39 ($P = .001$)
Y-Balance Test composite difference					Not correlated[a]	Not correlated[a]
Overhead squat score						Not correlated[a]
Landing Error Scoring System score						

[a] $P > .05$.

DISCUSSION

Our primary goal was to provide normative data for a battery of functional movement tests developed to assess core stability, functional movement patterns, and dynamic balance. The screens were performed by applicants who were entering basic training in the US Army, Navy, Air Force, or Marine Corps. In addition, the relationships among these movement screens were explored to identify any potential overlap in risk-factor identification and assist in reducing the array of tests. More than 1000 military applicants were successfully enrolled, and several baseline movement assessments were conducted in this cohort on the day they shipped to basic training. Sex-normative values for the FMS, YBT, OHS, and LESS screens have been established, and we saw some overlap in these assessments. Notably, we are the first, to our knowledge, to evaluate these screens in military applicants before basic training. Overall, male applicants performed better on the OHS and LESS and achieved greater YBT-Comp% than female applicants. Regression results revealed movement screen performance relationships that varied by sex. In future studies, we will examine if performance on any of the screens is associated with increased risk for MSK-Is in military basic trainees.

Several interesting findings emerged from these specific clinical screening tests. First, FMS scores for the males and females in this cohort were 1 to 2 points lower than those reported in other military populations[27,28] and professional football players[29,30] but similar to those reported in several collegiate populations[15] and deploying Marines.[31] According to these studies, as a group, our cohort of applicants entering basic training would be considered high risk, as their mean FMS scores were 14.8 and 14.4 for males and females, respectively. Given that MEPSTART is tracking injuries throughout basic training, population-specific cutoffs for injury risk in this cohort should become available in the future.

Our participants' YBT-Comp% averages were also lower than reported for other military and active populations.[22,27,32] Plisky et al[22] determined that high school basketball players who achieved 94% or less of composite reach on the modified Star Excursion Balance Test (a precursor to the YBT) were more likely to sustain a lower extremity injury during the season. In our study, males

Table 6. Regression Analyses Representing the Final Model for the Test of Interest for Males Within Each Column

	1. Functional Movement Screen Composite Score (n = 361)	2. Y-Balance Test Anterior-Reach Difference (n = 803)	3. Y-Balance Test Composite Percentage (n = 732)	4. Y-Balance Test Composite Difference (n = 849)	5. Overhead Squat Score (n = 361)	6. Landing Error Scoring System Score (n = 370)
Explanatory variables	Y-Balance Test composite percentage = 0.38 ($P < .001$) Overhead squat score = −0.44 ($P < .001$)	Y-Balance Test composite difference = 0.28 ($P < .001$) Overhead squat score = 0.08 ($P = .01$)	Functional Movement Screen = 0.40 ($P < .001$) Overhead squat score = −0.30 ($P < .001$)	Y-Balance Test anterior-reach difference = 0.32 ($P < .001$)	Functional Movement Screen = −0.44 ($P < .001$) Y-Balance Test composite percentage = −0.29 ($P < .001$) Landing Error Scoring System score = 0.19 ($P < .001$)	Overhead squat score = 0.18 ($P < .001$)
Observed R^2	0.27	0.08	0.18	0.10	0.23	0.03
Adjusted R^2	0.26	0.08	0.18	0.10	0.23	0.03
P value	<.001	<.001	<.001	<.001	<.001	.001
Cohen f^2	0.35[a]	0.09	0.22[b]	0.11	0.30[b]	0.04

[a] Large Cohen f^2 ($\geq$0.35).
[b] Medium Cohen f^2 (0.14–0.34).

Table 7. Regression Analyses Representing the Final Model for the Test of Interest for Females Within Each Column

	1. Functional Movement Screen Composite Score (n = 129)	2. Y-Balance Test Anterior-Reach Difference (n = 151)	3. Y-Balance Test Composite Percentage (n = 74)	4. Y-Balance Test Composite Difference (n = 136)	5. Overhead Squat Score (n = 130)	6. Landing Error Scoring System Score (n = 84)
Explanatory variables	Y-Balance Test composite percentage = 0.42 ($P < .001$)	Y-Balance Test composite difference = 0.20 ($P = .007$)	Functional Movement Screen = 0.41 ($P < .001$) Landing Error Scoring System score = −0.32 ($P = .003$)	Y-Balance Test anterior-reach difference = 0.25 ($P = .002$) Y-Balance Test composite percentage = −0.18 ($P = .02$)	Y-Balance Test composite percentage = −0.24 ($P = .003$)	Y-Balance Test composite percentage = −0.32 ($P = .002$)
Observed R^2	0.18	0.04	0.25	0.10	0.06	0.10
Adjusted R^2	0.17	0.03	0.23	0.09	0.05	0.09
P value	<.001	.01	<.001	.001	.005	.003
Cohen f^2	0.22[a]	0.04	0.33[a]	0.11	0.06	0.11

[a] Medium Cohen f^2 (0.14–0.34).

reached only 91.3% and females only 88.7% of leg length, values that are much lower than the 103% and 98% of leg length reported for male and female high school basketball players, respectively.[22] The YBT-Adiff values in our group were similar to previously reported values in similarly aged populations.[16,33]

The OHS is a valid indicator of lower extremity biomechanics,[34] specifically medial knee displacement. However, kinematic differences have been noted between males and females when they perform the OHS.[35] To our knowledge, no other researchers have presented normative data for this functional movement assessment, so interpretation of error scores is difficult. Interestingly, males performed the test with fewer errors than females, but the most common error observed across both sexes was medial knee displacement (in 44% of males and 58% of females) followed by arch flattening (in 52% of males and 50% of females). Whereas tests are potentially identifying movement errors as defined by our scoring system, we are unsure if these errors reflect an increased injury risk at this time.

The LESS has been shown to reliably identify biomechanical deficits that may predispose an individual to lower extremity injury.[36] Performance on the LESS has successfully predicted injury in youth soccer players with high specificity and moderate sensitivity.[37] Although our results indicated that females displayed more errors than males, it is unclear what these differences mean. Unfortunately, these scores cannot be directly compared with the literature due to the updated LESS scoring rubric used in our study, but the sex differences deserve further attention. DiStefano et al[25] reported that female youth soccer players had higher (worse) LESS scores than males both before and after a movement retraining program. However, whereas Smith et al[38] demonstrated that high school and collegiate male athletes had higher mean LESS scores than female athletes, they did not find mean sex differences in athletes who eventually tore their anterior cruciate ligaments. In future studies, we will examine if sex differences in LESS scores affect risk for MSK-Is in our population.

In summary, we examined 4 of the many functional movement tests that are available. We used multiple linear regression analysis techniques to examine associations among the various tests so redundant measures could be eliminated, but the injury-prediction ability of these screens remains to be seen. Our most stark finding was that females showed different associations on movement screens, which further justifies our use of sex-specific modeling techniques. In females, the FMS was moderately associated with YBT-Comp% scores, and the YBT-Comp% was moderately associated with FMS and LESS scores. The tests are thorough, but multiple tests increase the total time required of both the tester and participant. Therefore, we sought to identify associations among test performances to potentially decrease the number of tests and time required. The intent of MEPSTART is not to use all of the movements but rather to create an assessment that is valid, field expedient, easy to execute, and most importantly, predictive. Whereas authors of initial studies[22,29] found associations among movement screens and eventual injury, several other researchers[38,39] have not. Regardless, the sensitivity and specificity of predictive screens remain poor, meaning that the time required for screening may not be worth the effort. To justify their use, research should continue to be directed toward identifying whether these risk factors predict future injury during basic training for each sex.

Clinical Relevance

A sex-specific overlap existed in performance on the FMS, YBT, OHS, and LESS. We observed clinically important relationships among measures for each sex, including those among FMS, YBT-Comp%, and OHS in males and between FMS and YBT-Comp% in females. To a lesser extent, the LESS also showed associations with the OHS in males and the YBT-Comp% in females. If time is limited, clinicians might consider using 1 of these screens to assess movement. However, given that these screens have previously shown only low to moderate predictive value for MSK-Is[16,17,29] and no 1 test or set of tests has been identified as clearly predicting MSK-I risk in our population, universal recommendations on the omission or inclusion of 1 test over another cannot be made.

Limitations

Our study had limitations. First, we possibly encountered some selection bias, as volunteers self-identified as willing to participate in a study about injury risk factors in a military environment. Volunteers could have been concerned about their injury risk and, therefore, not representative of the applicant population as a whole. Conversely, it was also possible that the most fit volunteered, and individuals who were concerned about injury risk did not want to participate. Regardless, all participants were cleared by MEPS personnel and their respective service to begin training; thus, the introduction of any additional bias was not likely. Second, not all participants were tested by the same individual, so intertester differences could have emerged. However, given that we had more than 1000 volunteers and ample statistical power to detect true differences, these effects most likely were minimal. In future studies, we will determine the relevance of our findings.

CONCLUSIONS

The FMS, YBT, OHS, and LESS are easy-to-perform clinical screens used to identify multijoint, multisegmental integrated movement patterns that may place applicants at risk for MSK-Is during basic training. Sex-specific overlap appears to exist in these assessments. In future work, we will examine if 1 screen or a combination of movements derived from the multiple screens is most predictive of MSK-Is in our cohort during basic training. Such findings could lead to the development of injury-prevention efforts that address these risk factors before individuals enter basic training. The culmination of these efforts could not only contain the already high training and medical costs, but more importantly, potentially protect future service members from preventable MSK-Is.

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