



The Relationship Between Health and Movement Screens and Field-Based Physical Fitness Tests in Reserve Officer Training Corps Students

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ABSTRACT

International Journal of Exercise Science 16(4): 42-52, 2023. The purpose of the present study was to evaluate the relationship between scores achieved in physical fitness tests and outcomes of health and movement screens (HMS) in ROTC students. Twenty-eight students (20 males: 21.8 yrs [\pm 3.4] & 8 females: 20.7 yrs [\pm 1.8]) enrolled in an ROTC branch (Army, Air Force, Navy, or Marines) completed a series of screens, including body composition analysis via Dual-Energy X-Ray Absorptiometry (DXA), balance and functional movement tasks via a lower-quarter Y-Balance test, and knee and hip joint concentric strength testing on an isokinetic dynamometer. Official ROTC PFT scores were collected from the respective military branch leadership. HMS outcomes were compared to PFT scores via Pearson Product-Moment Correlation and linear regression analyses. Across branches, total PFT scores were significantly correlated to visceral adipose tissue ($r = -0.52$, $p = 0.01$) and android:gynoid fat ratio ($r = -0.43$, $p = 0.04$). Visceral adipose tissue ($R^2 = 0.27$, $p = 0.011$) and android to gynoid ratio ($R^2 = 0.18$, $p = 0.042$) significantly predicted total PFT scores. No further significant correlations between HMS and overall PFT scores were observed. HMS scores revealed significant bilateral differences in lower extremity body composition ($p < 0.001$; $d = 0.23$) and strength ($p = 0.002$; $d = 0.23$). Across ROTC branches, HMS were poorly correlated with PFT performance yet indicated significant bilateral differences in lower extremity strength and body composition. The inclusion of HMS may ease the increasing injury rate among the military population by assisting in detection of movement shortcomings.

KEY WORDS: Physical fitness; injury prevention; ROTC; body composition; clinical assessment

INTRODUCTION

Physical fitness plays an important part in the life of a Reserve Officer Training Corps (ROTC) student. Across branches, weekly physical training (PT) sessions include weight workouts, marches and field-based activities. Additionally, ROTC students conduct physical fitness tests (PFTs) to assess their ability to adhere to branch specific physical requirements. The PFTs provide insight into the student's physical fitness, offer motivation to partake in regular physical

activity, and function as scholarship and commissioning qualifiers. PFTs are field-based tests designed for ease of evaluating physical abilities by evaluating multiple students at the same time using minimal equipment and are focused on muscular and cardiovascular fitness. At the time of the present study, PFT exercises used for the ROTC Air Force and Navy branches were 2-minute push-ups and sit-ups, and a 1.5-mile run, while the Army branch PFTs consisted of 2-minute push-ups and sit-ups, and a 2-mile run. Marine branch ROTC students complete timed pull-ups, abdominal crunches, and a 3-mile run. ROTC Students are scored according to each individual skill, along with a cumulative score to assess their physical ability and provide an evaluation score. The evaluation score allows for further differentiation between cadets, categorizing the cumulative scores as fail, good, excellent, or outstanding. When students score too low, they may be assigned to extra training sessions in addition to their current ROTC PT demands. If students fail to meet fitness standards, they may lose scholarship or ultimately fail to be commissioned to active duty. Thresholds for the PFT scores are used by the United States military based on potential relationships to injury risk and abilities to perform physical tasks while on active duty (35, 36).

However, field-based tests lack the ability to deliver accurate assessments of fitness or predict the likelihood of injury (35), which has caused many branches to alter their PFT skills over the past decade. For example, the Army ROTC have altered their testing from the Army Physical Fitness Test to the Army Combat Fitness Test (36).

The rate of musculoskeletal injuries (MSKIs) is of particular concern to the US military and ROTC programs due to time lost and healthcare cost (20). In recent years, ROTC programs and branches have noted an increase in MSKI rates, specifically in the lower extremities (12, 31). Lower extremity MSKIs are reported to contribute up to 85% of all training-related injuries in ROTC students (32). High rates of MSKIs have been hypothesized to relate to general lack of fitness upon entering ROTC unit, overtraining in response to PT sessions, neuromuscular and musculoskeletal fatigue, ROTC specific gears used for activities outside the PFTs (i.e., footwear, equipment sacks), and service activities (32). Entering the ROTC unit with low physical fitness increases MSKI risk due to the rapid increase in physical demand on the musculoskeletal system (22). One of the challenges with using PFTs as the sole tool to assess fitness level and potentially identify MSKI risk factors of ROTC students is the lack of evidence that high scores at a specific exercise have the capability for performance and injury risk screening (23). Thus, other approaches are necessary to address the rate of MSKIs in ROTC students.

Current PFTs are designed to focus on speed, muscular strength and endurance irrespective of bilateral differences in motor and strength abilities. However, prior investigations have demonstrated that potential asymmetries in the lower extremities, whether those differences are related to strength (11), body composition (24), or functional mobility (6) may be predictive of future MSKIs in a military population. The current PFTs do not assess bilateral tasks, rather they report number of repetitions and speed at which a run is completed. Implementation of these testing sessions through military branch observation and scoring may be an indicator for physical fitness that is functional, quick, and easy to execute. Yet, implementing screens that

assess bilateral differences within the lower extremities of the students may assist the ROTC programs in reducing MSKI rates.

Functional movement, strength, and body composition screens have been used as assessments of health and fitness and to predict MSKI risk (28). These health and movement screens (HMS) may provide foundational context of functional health that underscores the performance outcome during PFT. Body mass index (BMI) is commonly used in the military to assess body composition and profession suitability but fails to account for differences in lean and fat mass, and distribution of fat mass (34). Alternatively, Dual Energy X-Ray Absorptiometry (DXA) provides information about bone health, fat and lean mass, and visceral adipose tissue. The ability of the DXA to analyze these variables segmentally (separating lower and upper extremities and left to right side of the body) allows for more specific analyses and a more localized approach when it comes to implementing an injury prevention program (18). Bilateral differences in lean mass, as detected via DXA, or musculoskeletal strength asymmetries in the lower extremities as measured via isokinetic dynamometry, have been associated with a greater risk of knee injury in a military population (11).

In addition to measures of body composition and strength, functional mobility and stability of motor patterns have been used to evaluate asymmetry and MSKI risk. The Y-Balance Test (YBT) assesses an individual's ability to maintain balance and postural control while maintaining one stationary limb and moving a reach indicator with the contralateral limb in three different directions. A YBT may indicate bilateral asymmetry as both limbs undergo the same procedure to complete the test. Lower cumulative scores and anterior reach of the lower-quarter YBT overall and between limbs have been associated with a two times greater risk for MSKIs (16). Additionally, lower scores on the upper-quarter YBT have been found to be associated with an increased injury risk in coast guard candidates (6).

The implementation of additional screening protocols may assist in developing strategies to maximize performance outcomes while mitigating MSKI risk by identifying potential bilateral asymmetries. Thus, the purpose of the present study was to evaluate the relationship between scores achieved in physical fitness tests and outcomes of health and movement screens in ROTC students.

METHODS

Participants

A power analysis conducted with G*POWER 3.1 (Universität Kiel, Germany) for the relationship analyses determined that 19 participants were needed in the present study for a correlation of 0.6, power of 0.80, and an $\alpha = 0.05$. Twenty-three ROTC students from four different military branches (Air Force, Army, Navy, Marines) participated in the health and movement screens. Official PFT scores for each participant were supplied by the individual military branch leadership. Active enrollment in the ROTC program and recent completion of their respective military branch PFT was required for participation eligibility. Participants were apparently

healthy and did not display or report any musculoskeletal injuries or cardiorespiratory illnesses at the time of recruitment and data collection as reported by each military branch leadership. Ethics approval was obtained by the University's Institutional Review Board. Informed consent was obtained by all participants prior to participation in the study. This research was carried out in accordance with the ethical standards of the International Journal of Exercise Science (27).

Protocol

Participants underwent three health and movement screens: body composition, Y-Balance, and isokinetic dynamometry. Dual Energy X-Ray Absorptiometry (DXA) (Hologic Inc., Horizon QDR Series, Bedford, MA, USA) was used to evaluate body composition including total and segmental fat mass (FM; kg and %) and lean mass (LM; kg), visceral adipose tissue area (VAT; cm²), and android fat (AF) to gynoid fat (GF) ratio (AG ratio). Additionally, BMI (kg/m²) was calculated. Each DXA scan included one anteroposterior view of the whole-body lying supine and was conducted and analyzed by the same DXA trained researcher. Full-body scans were segmented manually and determined in the following manner: Lower extremities were segmented inferiorly to the pubic symphysis and superiorly to the neck of the femur; upper extremities were segmented through the scapulohumeral joint. VAT was determined by segments separating subcutaneous and visceral fat. AG ratio was generated by the scanner software, determining android region between the anterior aspect of the pelvis and halfway along the lumbar spine, and gynoid region between the mid-point of the thigh and the head of the femur.

Participants completed a lower- and upper-quarter Y-Balance test (YBT) for both right and left side. Participants performed six practice trials for each limb and each direction (anterior, posteromedial, posterolateral). Three successful trials were recorded per limb and direction. A trial was considered successful when the participant did not lose balance throughout the motion, did not touch the floor with the moving limb, and did not touch the top of the moving block during the motion. All participants performed the lower extremity test barefoot and were allowed to use their arms to maintain balance during the test. All participants performed the upper extremity test in a plank position and were allowed to flex the elbows of the support limb throughout the reaching motion. A single examiner scored each trial, reporting the furthest reach in each direction. Each reach was normalized to stance limb length and combined to form a lower composite (LC) and upper composite (UC) score for both the left and right side. The composite score was calculated with the sum of the furthest reach for each of the three directions, divided by the measured limb length, then multiplied by 100.

Lower extremity strength was assessed in a series of eight concentric muscle action tests on the isokinetic dynamometer (HUMACNORM, CSMI, Stoughton, MA, USA). Participants performed two separate movements at two different angular velocities per limb (right and left), Knee flexion/extension at 90°/s and hip adduction at 180°/s. For each maximal effort test, participants performed three practice trials followed by ten seconds rest before completing five test trials. Peak torque (Nm) values were collected and normalized to body mass to obtain

relative peak torque values (Nm/kg). Sufficient breaks and hydration ad libitum were provided after and during each assessment to diminish fatigue effects during the testing.

PFT Scores: Official PFT scores were supplied by each military branch leadership, de-identified and recorded in a master sheet. Three branches (Air Force, Army, & Navy) follow a similar structure for their PFTs, while the Marine branch has their own set of field-based exercises. The exercises used for the Air Force and Navy PFTs were push-ups, sit-ups, and a 1.5-mile run. The Army PFTs consisted of push-ups, sit-ups, and a 2-mile run. The Marine PFTs consisted of pull-ups, abdominal crunches, and a 3-mile run. Additional differences between branches can be found in the time allotted to each exercise. While the Air Force branch allows 1-minute trials for push-ups and sit-ups, the Army and Navy branch allow 2-minute trials for each exercise. The Marine branch allows 2-minutes to complete as many abdominal crunches as possible. Further differences appear in the cumulative scoring for each branch. Army and Marine weigh the PFT components equally, assigning a maximum of 100 points for each test resulting in a total score of 300. Air Force and Navy assign weighted scores to the PFT components leading to a total score of 100 points. Due to the difference in the PFT assessments and scoring among the branches, total PFT scores of the participants were normalized to fit a scale of 0-100 to allow for a combined analysis for all branches. In order to fit the Air Force and Navy scale of 0-100, Army and Marine scores were normalized using the following formula:

$$\text{Normalized PFT Score} = \left(\frac{(\text{Cadet PFT Score} - \text{Minimum Scale Value})}{(\text{Maximum Scale Value} - \text{Minimum Scale Value})} \right) \times 100$$

After normalization, total PFT scores of all branches followed the same scale. The total scores analyzed in the present study were based on the individual rating scales provided by the military branch leadership.

Statistical Analysis

All statistical analyses were completed for the entire sample population, combining participants from each military branch. Pearson product-moment correlation coefficient analyses were conducted to evaluate the relationship between official PFT scores and their respective HMS outcomes. Paired sample *t*-tests were conducted to explore possible differences between limbs for each health and movement screen. Effect sizes (Cohen's *d*) were computed upon occurrence of significant differences between limbs. A Cohen's *d* value for effect size was interpreted as small, medium, or large at values 0.2, 0.5, and 0.8 respectively. Additionally, linear regression analyses without prior baseline adjustments were conducted to explore the predictive relationship of each HMS outcome (explanatory variable) for total PFT scores (dependent variable) per ROTC branch. Alpha level was set to 0.05 a priori. Statistical analyses were completed via SPSS version 28.0 (IBM, Armonk, NY).

RESULTS

Table 1 displays the distribution of participants among the ROTC branches, individual branch demographic data, and significant difference ($p = 0.036$) in percent FM between Army (28.9%) and Marine (21.7 %) participants.

Table 1. ROTC Student Distribution and Mean (\pm SD) Demographics per Branch

	Air Force	Army	Navy	Marines
Total Participants ($n = 23$)	9	3	6	5
Male Participants ($n = 18$)	6	2	5	5
Female Participants ($n = 5$)	3	1	1	0
Height (cm)	178.2 (10.0)	180.3 (7.5)	174.8 (10.2)	182.0 (3.7)
Mass (kg)	77.6 (14.1)	88.8 (3.1)	76.6 (19.2)	84.8 (5.7)
BMI (kg/m^2)	24.3 (2.8)	26.8 (6.4)	24.7 (3.9)	25.6 (1.8)
Age (yrs)	21.0 (0.9)	22.8 (3.8)	21.4 (3.3)	21.8 (4.1)
FM (%)	22.7 (4.6)	28.9 (3.9) [†]	22.7 (5.7)	21.7 (4.4) [†]

Note. ROTC, Reserve Officer Training Corps; SD, Standard Deviation; BMI, Body Mass Index; FM, Fat Mass. [†]Significant difference ($p = 0.036$) between Army and Marines FM.

Across all ROTC branches combined, total PFT scores showed significant correlations to percent FM ($r = -0.45$, $p = 0.032$), VAT ($r = -0.52$, $p = 0.011$), and AG ratio ($r = -0.43$, $p = 0.042$). No significant correlations were found for LM (kg) ($r = -0.32$, $p = 0.13$), FM (kg) ($r = -0.17$, $p = 0.42$), and BMI ($r = -0.39$, $p = 0.07$).

No significant correlations between total PFT scores and Y-Balance Test variables were found [LC Left ($r = -0.07$, $p = 0.73$), LC Right ($r = -0.23$, $p = 0.28$), UC Left ($r = 0.40$, $p = 0.06$), UC Right ($r = 0.24$, $p = 0.28$)].

No significant correlations between total PFT scores and isokinetic dynamometer variables were found [Knee Flexion Right ($r = 0.38$, $p = 0.32$), Knee Flexion Left ($r = 0.51$, $p = 0.13$), Knee Extension Right ($r = -0.13$, $p = 0.78$), Knee Extension Left ($r = 0.57$, $p = 0.13$), Hip Adduction Right ($r = -0.33$, $p = 0.41$), Hip Adduction Left ($r = -0.23$, $p = 0.72$)].

Multiple single variable linear regression analyses for all branches combined showed no significant prediction abilities of any HMS score except for VAT ($R^2 = -0.27$, $F(1, 21) = 7.79$, $p = 0.011$) and AG ratio ($R^2 = -0.18$, $F(1, 21) = 4.70$, $p = 0.042$) across all branches. Greater VAT area and AG ratio were significantly related to lower normalized overall PFT scores.

Statistically significant differences were found between left and right lower extremity lean mass, and right and left relative knee extensor peak torque (Table 2). Effect sizes were small. No other HMS showed significant bilateral differences among the ROTC students.

Table 2. Left and right mean (\pm SD) and *t*-test results for lower extremity lean mass and relative knee extension

Variable	Left Leg	Right Leg	Results		
			<i>p</i>	<i>t</i> -score	Effect size
Lean Mass (kg)	10.02 (2.22)	10.40 (2.29)	< 0.001 [†]	7.31	0.23
Knee Ex PT (Nm/BM)	2.23 (0.29)	2.30 (0.29)	0.002 [†]	3.49	0.23

Note. SD, Standard Deviation; Ex, extension; PT, peak torque; Nm/BM, Newton-meter per kilogram body mass.
[†]Significant difference.

DISCUSSION

The purpose of the present study was to evaluate the relationship between scores achieved in PFT and outcomes of HMS in ROTC students. The main finding of the study was the overall weak correlation between HMS scores and PFT scores. Despite the lack of significant correlations across branches, the significant bilateral differences in lower extremity relative peak torque and lean mass provide evidence for the implementation of HMS alongside PT and PFTs. While the aforementioned HMS may not be regularly used to assess and predict performance, their ability to detect bilateral asymmetries and functional movement shortcomings may assist in diagnosing, predicting, and preventing injuries in ROTC students.

The present study found that total PFT scores had a negative relationship to VAT and AG ratio across all branches. An individual with greater VAT area or AG ratio reported lower PFT scores, suggesting that a higher amount of VAT, as well as a higher AG ratio may have a detrimental effect on ROTC student PFT performance. VAT is intra-abdominal adipose tissue lining organs for protection, yet increased amounts have been shown to be heavily correlated to increased risk for metabolic and cardiovascular diseases (8, 14). AG ratio is the ratio between the amount of fat distributed around the abdomen (android) in comparison to the hip (gynoid). A ratio greater than 1 suggests fat to be distributed primarily around the abdomen, which, coinciding with VAT, has been found to be correlated to increased risk for cardiovascular diseases (25). The ROTC program has a history of using BMI and waist circumference data as indicators of body composition, health screening, and soldier selection criteria (15). However, such methods lack the distinct ability to separate LM and FM, determine VAT area, and properly assess the distribution of body fat. Moreover, fat distribution has been shown to be a better predictor for diseases than BMI (15).

Furthermore, BMI has been found to be poorly correlated to ROTC PFT scores (30, 31). While the US military has introduced other body composition assessments, such as skin calipers to estimate FM (%), research has indicated that VAT, rather than subcutaneous adipose tissue, may be the strongest indicator of cardiovascular and metabolic disease risk (37). Additionally, research has linked greater VAT and AG ratios to a significantly lower cardiorespiratory fitness (1, 2, 9, 38). Thus, the present findings suggest a connection between both VAT and AG ratio and PFT performance due to potentially detrimental effects on cardiorespiratory fitness of the ROTC students. The implementation of DXA scans to provide body composition data

complimentary to PFTs may provide an opportunity to improve a student's performance and decrease risk of disease.

Research has identified that less body mass, further indicated by lower BMI ratings, is correlated with greater overall PFT scores (30). Yet, given the inconsistent correlation results, it can be argued that these findings align with previous literature indicating that body composition variables such as BMI or overall FM and LM are generally poor predictors of physical performance in ROTC students (21, 34). Studies have investigated levels of overall FM (%) and abdominal obesity in relation to developing cardiovascular diseases and found that risk for disease increases as FM (%) and obesity increase (10, 29, 39). Thus, these measures appear to be of value for the ROTC in terms of determining risk for disease, rather than performance prediction.

The present study did not find any meaningful correlations between Y-Balance test scores and PFT performance across all branches. Functional movement screens, such as the Y-Balance test, have been previously used with ROTC students to assess potential risk factors for injury (13). Previous literature investigating isokinetic strength and PFT performance among ROTC students is limited. Generally, isokinetic strength has been found to be significantly correlated to athletic performance in various populations (3, 5, 17). This correlation was not found in the present study. However, significant differences were found between right and left maximal isokinetic knee extension relative and absolute peak torque values. Previous research observed that Special Operators within the Air Force who reported a previous knee injury showed a greater difference in knee extensor strength in contrast to previously uninjured individuals (11). Generally, bilateral strength asymmetries have been associated with increased risk of lower extremity injury (7, 26, 33). The bilateral differences in isokinetic strength among ROTC students found in the present study may increase risk and likelihood of injury, despite a successful completion of the PFT. Thus, it can be argued that branches across the ROTC may benefit from an addition of isokinetic dynamometer assessments alongside the PFTs. Further research is necessary to investigate the cause of the strength difference and determine injury rates in ROTC students who successfully complete their PFTs yet display lower extremity strength asymmetries.

As ROTC students who participated in the HMS all passed their individual PFTs, findings should be interpreted with caution. Students who failed their PFTs or were injured did not participate in the laboratory session. Future studies should aim to include a sample of ROTC students who pass and fail the PFT requirements. Another limitation of the study is the sample size. Only 23 participants qualified for data analysis, as some of the participants were medically exempt from one of the three physical fitness test. Further, the number of participants were unevenly split among the ROTC branches. An increase in the total number of participants would have improved the multiple regression analyses and effect sizes of the results. Lastly, participants were instructed to take as many breaks and consume as much liquid as needed between each test in order to avoid musculoskeletal and neuromuscular fatigue. The isokinetic

dynamometer was the last test completed during the session and fatigue may have played a factor in the asymmetric isokinetic strength values.

In line with the bilateral strength asymmetry, a significant bilateral difference was found for lower extremity lean mass. Previous research on lower limb lean mass differences indicates that muscle cross section asymmetry may be related to a higher risk for lower extremity injuries (24). Additionally, lower limb lean mass asymmetry has been found to cause asymmetry in force and power production, which may also increase the risk of injury (4, 19). As with peak torque, these bilateral asymmetries are likely to remain undetected by PFT scores, which may lead to an improper assessment of injury risk. Therefore, the addition of HMS within the ROTC may provide valuable information regarding body composition, strength, and asymmetries, which are inherently more predictive of injury risk compared to field-tests.

Conclusion: In conclusion, the findings of the present study suggest a weak relationship between ROTC physical fitness test scores and health and movement screens. Only two body composition variables (visceral adipose tissue area & android-gynoid ratio) gathered from Dual-Energy X-Ray Absorptiometry scans showed significant relationship to overall PFT scores. The lack of significant relationships may suggest an inherent incapability of field-based physical examinations for injury screening. This was partly shown by the significant bilateral limb difference in lean mass and knee extensor and flexor peak torque. Future research should further evaluate the implications of body composition assessments beyond skin fold measurements, as well as bilateral differences found in health and movement screens for ROTC students and their respective physical fitness test performances and injury rates.

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