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Original Research

Anthropometrical and Physical Fitness Predictors of Operational Military Test Performance in Air Force Personnel

RAÍ T. SILVA†[1], FÁBIO A. D. CAMPOS‡[1,2], LEANDRA C. B. CAMPOS†[2,3], MONICA Y. TAKITO‡[4], EDISON M. MIRON‡[5], ÍDICO L. PELLEGRINOTTI‡[3], and EMERSON FRANCHINI‡[4]

[1]Postgraduate Program in Operational Human Performance, Air Force University, Rio de Janeiro, Rio de Janeiro, BRAZIL; [2]Federal Institute of Education, Science and Technology Goiano, Ceres, Goiás, BRAZIL; [3]Faculty of Health Sciences, Methodist University of Piracicaba, Piracicaba, São Paulo, BRAZIL; [4]School of Physical Education and Sport, University of São Paulo, São Paulo, BRAZIL; [5]Air Force Academy, Pirassununga, São Paulo, BRAZIL

†Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 13(4): 1028-1040, 2020. The objective of this study was to verify the relationships between the anthropometrical and physical fitness parameters (measured by the Physical Conditioning Assessment (PCA) of the Aeronautics Command), with the operational performance in the simulated military task performance (SMTP) performed by the infantry military of a Brazilian Air Force (BAF) unit. These evaluations were performed on two distinct days, interspersed by 48h, with PCA on the first day and the SMTP in the second. The distribution of the dependent variable was not normal (Shapiro-Wilk test, $p = 0.001$). Data are presented as mean and standard deviation, median and interquartile, for variables normally and non-normally distributed, respectively. The correlation between variables was determined using the Spearman's correlation coefficient. A regression model to predict performance in the SMTP, based on the anthropometrical, physiological and performance variables, was performed. The significance level was set at 5%. Based on the results, there was an association between all the PCA and SMTP variables: weight, lean body mass, trunk flexion, and estimated VO_2max based on the distance covered in the 12-minute test. The following equation was generated: SMTP (s) = 350.611 – 1.556 (fat-free mass, in kg) – 0.34 (12-min running distance, in m) – 0.632 (sit-up, in repetitions). The explained variance of the SMTP was 72.3% with an estimated standard error of 3.6s. It was observed that, although the association was diagnosed in some variables, there is a need to analyze possibilities for improvement in the selection of physical fitness tests that are closer to operationality in BAF Infantry military personnel.

KEY WORDS: Simulated military test, body composition, operational performance

INTRODUCTION

Well-developed fitness is considered a key parameter for military performance in their specific tasks. As an example, these activities involve sprinting, rushes, climbing, jumping, crawling, quick changes of direction, load carriage, obstacle trespassing, tactical actions, avoiding enemy fire, evacuating a casualty, and executing combative actions with load consisting of a personal weapon, combat gear, and protective equipment (8, 15) demanding both endurance and muscular strength (15). Moreover, army soldiers dealing with combat situations need adequate anaerobic capacity development to execute high-intensity actions and coordinated speed in rapidly changing life-threating conditions (15). In this sense, simulated studies to evaluate military performance have deserved the attention of researchers of the theme (8, 15), as well as studies that investigate the association between general physical fitness measures and military-specific performance (8, 15). Classically, physical fitness assessment is composed by body composition, strength, cardiorespiratory fitness, and flexibility (7).

Physical fitness is considered relevant for both training and real environments (6), which has been considered a parameter of job readiness and suitability, but also as a measure of health status and health-related risk factors (2). Physically demanding military operational tasks require skilled soldiers. Thus, determining which modifiable physical fitness components are associated with performance in such occupational tasks is essential to help these personnel to reach the desirable physical readiness for the military operations (8). In addition, some studies have shown that 90% of military performance scores on specific tests were used to release return of personnel to service in some regiments, as well as related performance on other performance tests on specific military tasks (2). In addition, increased physical fitness is considered a key element for injury prevention (6). Consequently, physical fitness and readiness for service are administered as a graduation requirement, which is observed every six months for active military personnel (6).

Specific military task tests can range from short duration, for example, in the Warrior Task Simulation Test, which lasts for about four minutes (8) to longer tests, such as in the Army Forest Guard Assessment Test, lasting about 40 minutes (2). Thus, physiological response and discriminant variables may vary between tests with different characteristics. Huang et al (8) conducted a study utilizing a short duration test simulating battlefield tasks, with healthy and physically active men (18 – 30 years), and reported that anaerobic capacity, aerobic power, body fat, agility and strength endurance were correlated with a specific military simulation task (r = 0.35 to 0.59) and that a Multiple model including aerobic power, agility, fat free mass, strength endurance and body fat predicted 52% of the variation in the specific military test. However, it is important to consider that this research was conducted with university students, not adapted to military tasks, which may have reduced the relationship between variables.

Still regarding simulated military tests, Pihlainen et al (15) demonstrated that the performance in countermovement jumps, 3000m running and flexion tests and skeletal muscle mass explained 66% of the variation of the simulated test performed in the study, but the soldiers were evaluated during their implantation soon after a 2-week acclimatization period. Based on the studies of the area, it seems consensus that Operational activities and combat actions demand a great deal of military conditioning (10, 11), which must be constantly evaluated to demonstrate its combat capability in different areas and types of stocks, regardless of region or country.

In Brazil, recent examples of Armed Forces actions can be cited mainly in missions linked to the guarantee of Law and Order, such as the participation during the strike of the Military Police of the state of Espírito Santo in 2017, the maintenance of Peace Forces in countries such as Haiti and the military intervention in the state of Rio de Janeiro in 2018. These are some actions taken by infantry military based on the Brazilian Air Force (BAF) Basic Doctrine (3). The Brazilian Air Force personnel is periodically assessed regarding their body composition, cardiorespiratory fitness, flexibility and strength-endurance (5) whose evaluation and conceptualization parameters are based on internationally renowned scientific research (5). However, these tests lack the specificity to the military actions (14).

Due to the lack of studies that investigate these factors, the purpose of this study was to verify the relationships between the anthropometrical and physical fitness parameters (measured via the Physical Conditioning Assessment (PCA) of the Aeronautics Command), with the operational performance in the simulated military task performance (SMTP) performed by the infantry military of a BAF unit. Our hypothesis was that the theoretical basis of the PCA is mostly focused on the definition of exercises, assessments and indexes aimed at promoting health. In this sense, the methods of measuring physical fitness provided for in the PCA may not correspond to the required operational physical capacities in a combat operation scenario experienced by the Air Force Infantry.

METHODS

Participants

To select the study participants (casually and intentionally from military personnel from a BAF military base), the following criteria were met: a) be an active duty military man, classified as a soldier; b) be voluntary; c) be a member of a Brazilian Air Force Unit; and d) have your health inspection valid without any medical restrictions that would prevent you from engaging in intense physical activity. An a priori sample size of 32 subjects was estimated considering a large effect size (w = 0.5), an α level of 0.05 and a power of 0.8. However, after meeting the criteria for participation in the study, 30 volunteers were selected. For the final sample, only the test results of 29 participants were analyzed, the results of one of the participants who did not complete the running test being excluded. All volunteers were male (age: 20.2 ± 1.3 years old; body mass 74.6 ± 10.3 kg; height 175.2 ± 6.8 cm) from BAF. The military carries out 2 days of physical training weekly. The physical activities was based on the considerations described in the Brazilian Army Manual, used as a guide to military physical training in the Brazilian Armed Forces (distributed into cardiopulmonary and neuromuscular training sessions). Prior to the beginning of the study, all participants were informed about all the objectives and procedures of the present study described in the Informed Consent Form (ICF), which was signed by all. All procedures were previously approved by the local ethics committee. This research was carried out fully in accordance to the ethical standards of the International Journal of Exercise Science (12).

Protocol

To standardize the conduct of the tests, all experimental sessions were performed at the same time of day and under similar weather conditions to eliminate possible variations in performance. In the first session, the tests provided for in the Physical Fitness Assessment and in the second session, the Simulated Military Task Performance. Participants completed two sessions, each conducted on separate days, at least 48 hours apart. The study design can be seen in Figure 1.

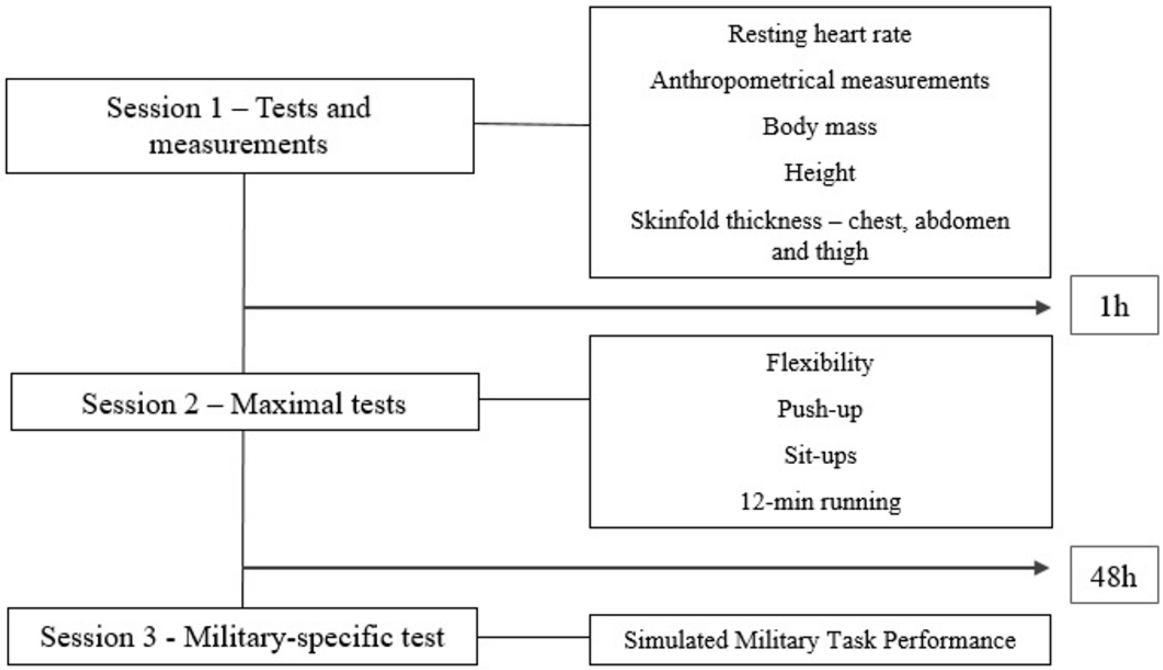

Figure 1. Study design

Regarding the variables, SMTP was considered the dependent variable, while PCA resulted in the independent variables.

The participants performed the PCA of the Aeronautics Command following the recommendations presented in the ICA 54-1 document (5), and the Simulated Military Task Performance (SMTP) as described by Pihlainen et al (15). All subjects were submitted to the anthropometrical measurements to estimate their body composition and to the physical fitness tests presented in the ICA 54-1. In order to avoid inter-rater variations, the assessment of each anthropometric variable in all subjects was performed by the same previously trained rater with 10 years of experience. These tests were conducted in the morning period of the first day of the investigation and 24h before the SMTP. According to the ICA 54-1 norms a strict sequence of testing and measurements were followed, including the use of the uniform to perform the test, which includes a short, a t-shirt and tennis shoes for Air Force personnel (4). Briefly, the sequence of tests and measurements were: resting heart rate, body mass, height, skinfold thicknesses (chest, abdomen and thigh), flexibility, push-up, sit-ups, and the 12-min running test (5). All military personnel, after the PCA, received a concept according to their result from cuts in the percentile tables (5). After these concepts, the arithmetic mean of the values obtained in the percentage of fat, flexibility, push-up, sit-ups, flexibility and 12-min running test.

In the following day, the subjects executed the SMTP (15), using the operational material, comprised by the camouflaged uniform (10th RUMAER uniform) (4), ballistic helmet, body armor, and an assault rifle and pistol. The track was composed by obstacles simulating an ambushing situation, where a displacement in combat context during an Air Force ground surface self-defense action (3).

Resting heart rate measurement: first, the resting heart rate (RHR) was measured after an interval of at least ten minutes lying supine. The measurement was performed through the radial artery of the left wrist, using the index and middle fingers of the right hand to count the beats for one minute. It is noteworthy that the hands were not raised during this measurement and that the RHR was counted in the unit beats per minute (5).

Body mass: to measure body mass, the military was in shorts, shirtless and barefoot (5). The value was registered in the kilogram unit to the nearest one decimal place (Welmy® W200A model, Santa Bárbara do Oeste, Brazil).

Height: height is the distance between the vertex, the highest point of the head, and the heel, in the lowest position. Therefore, this measurement was made using a stadiometer (Welmy® W200A model, Santa Bárbara do Oeste, Brazil) and the military was barefoot. At the time of the measurement, the military took a deep breath and kept the Frankfurt plane parallel to the ground, an imaginary line that runs through the lowest point of the eye socket and the highest point of the outer edge of the inner ear canal (5).

Skinfold thickness, body fat percentage and fat-free mass: skinfold measurements were taken in millimeter units using a plicometer (Cescorf® model, Porto Alegre, Brazil), recording the pectoral, abdominal and thigh skinfolds, in this order, necessarily. On the day of evaluation, the evaluated military was not subjected to physical exertion before the measurements. All measurements were collected three times and on the right side of the subject's body, with the skinfold regions analyzed bare and dry. The skinfold was clamped with the thumb and index finger so that the hand and the other fingers were resting on the body of the military being evaluated (5). For the measurement of the pectoral and abdominal skinfolds, the individual was standing with the arms extended along the body and with the legs apart, parallel and aligned to the trunk. To measure the skinfold thickness of the thigh, the military remained standing with the weight on the left leg, keeping the right lower limb relaxed.

Push-up: for this test, the evaluated military keep the body fully extended, with the front support on the ground so that the hands were slightly apart in relation to the shoulder projection. The body necessarily had to be extended at all times and the elbows protruded out at an angle of approximately 45 degrees to the trunk. The subject had only one attempt and performed as many repetitions as he could without a rest interval. The movement consisted of starting from the position with the arms extended, flexing the upper limbs to bring them as close as possible to the ground, passing the trunk of the elbow line, and extending them again returning to the initial position (5).

Sit-ups: to perform this test, the military was supine with his hands crossed to his chest at shoulder level, knees at a 90° angle, feet aligned with hip extension and firm to the ground. The feet were fixed to the ground with the assistance of another person stepping on them. The military man had only one attempt and performed as many repetitions as he could without stopping, during one minute. The movement consisted of flexing the trunk until the elbows touched the distal third of the thighs and then returning to the initial position with the shoulder blades touching the ground (5).

Flexibility: according to Araújo (1), the flexitest is a method of measuring and evaluating the maximum passive joint flexibility, comprising 20 movements (36, if considered bilaterally), in the joints of the ankle, knee, hip, trunk, wrist, wrist elbow and shoulder. Due to the excessively long time that would be necessary for the complete application of the flexitest in a large number of military, an adaptation with a smaller number of movements was made, composed of the shoulder, trunk and hip joints, aiming at its applicability in the Aeronautics (5).

12-min running test: the running test was performed by the maximum distance traveled by the military for twelve minutes, in a horizontal plane of inclination not exceeding 1/1000 meters (5). The 12 minutes run was performed on an official all-weather running track with 400m of length. The athletic track was marked every 10 meters to facilitate the measurement of the maximum distance achieved in the test. The values were recorded and the VO_2max was estimated using the following equation:

VO_2max = (maximum distance in meters − 504.9)/44.73 (5).

Equation 1

Overall Score: the military, after the execution of the PCA, must receive an overall score regarding his performance, which corresponds to the arithmetic average of the five percentiles referring to skinfolds, flexibility, pull-up, sit-up and the 12-minute run. RHR, body mass and height are not part of the Overall Score computation, serving only as complementary data (5). The percentiles are obtained by comparing the values collected in the tests with their respective percentiles established in the Percentile Tables contained in the ICA that regulates the PCA. It is noteworthy that the Overall Score has the peculiarity of being of paramount importance in the moral concept of the military, because among all the evaluations performed in the annual PCA of BAF, only the index of the Overall Score is linked to its relative merit.

Simulated Military Task Performance: the SMTP is presented in Figure 2A and 2B. Briefly, from the starting position of lying supine, the military performed four consecutive 6.32m quick runs, changing direction after each 6.32m step (zigzag). After the last rush they continued 11.3 meters by low crawl, followed by a sprint of 21.8 m. After the sprint, they ran another 21.8 m jumping over three 40 cm obstacles separated by a distance of 5 m. Thereafter, they lifted, carried and lowered two 16 kg kettlebells four times for a distance of 2.5 meters. This was followed by a zig zag run of 42.4 meters. Finally, before sprinting back to the starting line they dragged a 65 kg mannequin for a circle of 24 meters. The total length of the MST track was 242.5 meters (Figures 2A and 2B) (15).

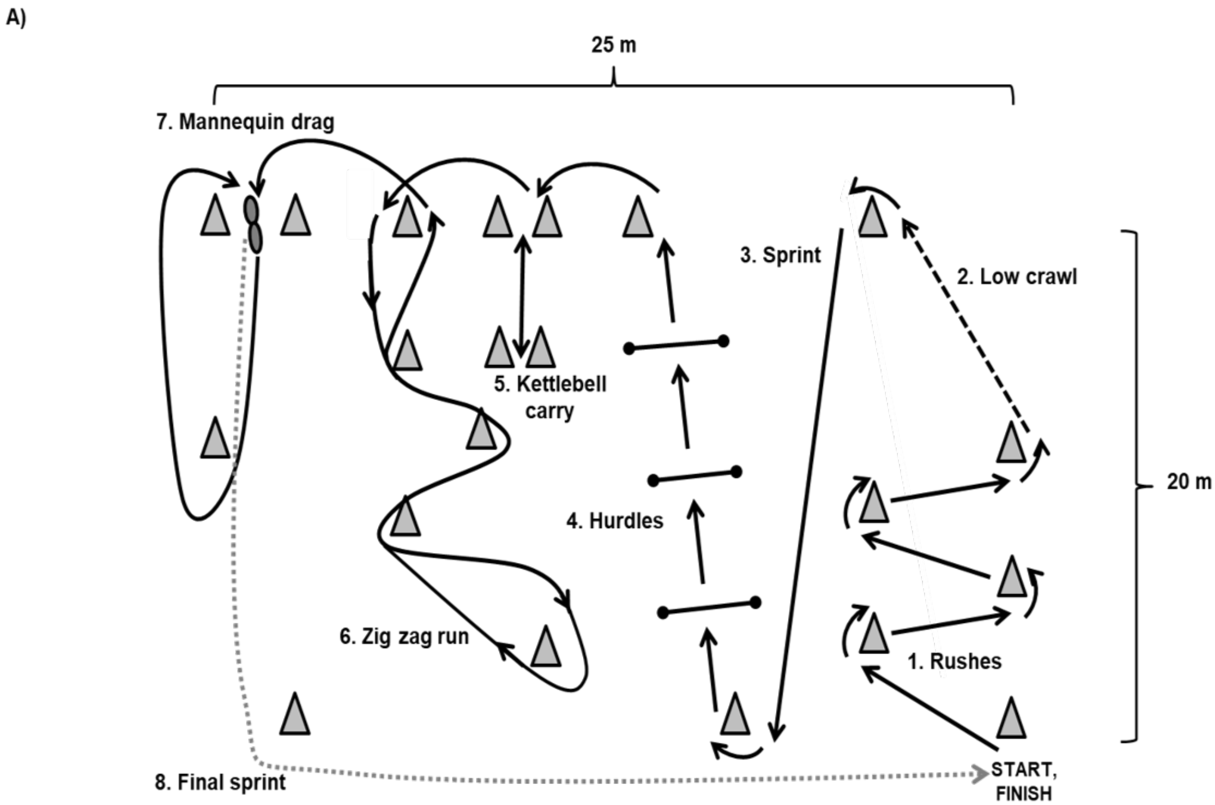

Figure 2A. Simulated Military Test Performance from Pihlainen et al (15).

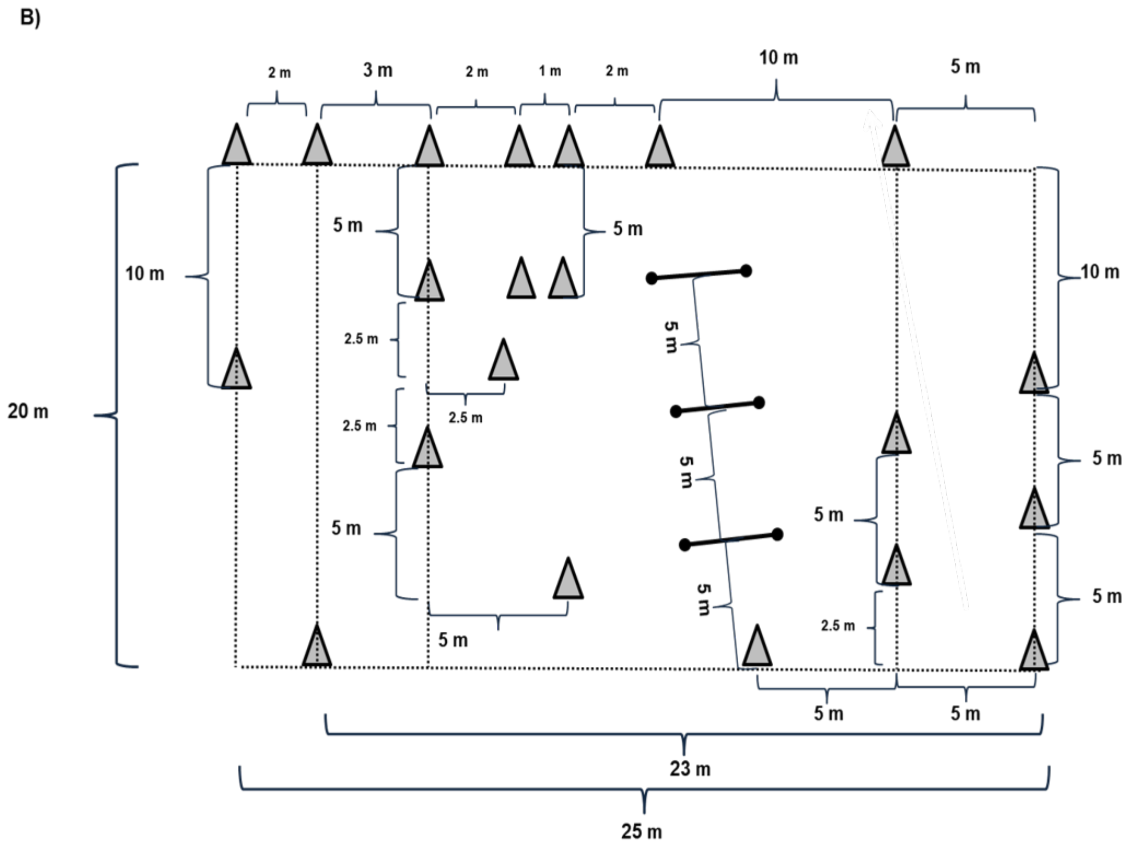

Figure 2B. Distances used of the Simulated Military Test Performance from Pihlainen et al (15).

Before executing the SMTP, each soldier was individually familiarized with the track by an instructor who also gave verbal instructions during the only execution. Subjects were instructed to perform the test as fast as possible. The time to execute the SMTP was the performance measure.

Statistical Analysis

The distribution of the dependent variable was not normal (Shapiro-Wilk test, p = 0.001). Data are presented as mean and standard deviation, median and interquartile, for variables normally and non-normally distributed, respectively. The correlation between variables was determined using the Spearman correlation coefficient. A regression model to predict performance in the SMTP, based on the anthropometrical, physiological and performance variables, was performed. Specifically, the Gamma Generalized Linear Model for Modeling was used because the dependent variable presented a positively skewed distribution and low values for Akaike's Information Criteria (AIC), bias-adjusted AIC and Bayesian- Information Criteria were observed (13). The significance level was set at 5%. Data were analyzed using SPSS 21.0 (SPSS Inc., Chicago, USA).

RESULTS

Table 1 presents the subjects' characteristics and performance in the physical tests.

Table 1. Age, anthropometry and physical fitness of Brazilian Air Force personnel (n = 29).

				Interquartile	
Variables	Mean	SD	Median	First	Third
Age (years)*	20.2	1.3	20	20	21
Body mass (kg)	74.6	10.3	75.0	68.0	79.5
Height (cm)	175.2	6.8	175.0	170.0	179.5
Body mass index (kg/m^2)	24.3	3.0	24.4	22.4	25.7
Resting heart rate (bpm)	70	10	70	64	74
Chest skinfold (mm)*	9	5	9	6	11
Abdominal skinfold (mm)	20	9	20	14	26
Thigh skinfold (mm)	19	8	17	15	25
Sum skinfolds (mm)	48	19	46	37	60
Body fat (kg)	10.0	5.4	8.7	6.5	13.1
Body fat (%)	13.0	5.6	12.8	9.7	16.7
Fat-free mass (kg)	64.6	7.1	65.5	59.6	69.7
Flexibility (scale)*	15	3	14	13	17
Push-up (rep)	41	9	40	35	50
Sit-up (rep)*	50	9	51	47	55
12-min running (m)	2661	233	2695	2530	2810
Overall Score (percentile)	82.9	11.5	83.0	77.0	90.5
Simulated Military Test (s)*	126.9	21.2	121.9	112.2	137.2

* non-normally distributed, Test of Normality Kolmogorov-Smirnov ($p < 0.05$), SD = standard deviation
kg – kilograms, cm – centimeters, m – meters, bpm = beats per minute, mm – millimeters, % - percentage, rep – repetitions, s – seconds.

The multiple regression analysis indicated that the time in the SMT could be predicted by fat-free mass, and performance in the sit-up and 12-min running test. The following equation was generated:

SMTP (s) = 350.611 – 1.556 (fat-free mass, in kg) – 0.34 (12-min running distance, in m) – 0.632 (sit-up, in rep).
Equation 2

The explained variance of the SMTP, based on these variables, was 72.3% (D2 = 0.723), with an estimated standard error of 3.6s.

DISCUSSION

The main findings of the present study were a longer distance completed in the 12-min running test (rs = -0.599), a heavier free-fat mass (rs = -0.483) and a higher number of repetitions in the sit-up test (rs = -0.415) were correlated with shorter time in the SMT. The moderate inverse correlations suggest that higher skeletal muscle mass might improve military specific anaerobic performance. Additionally, these variables combined explained 72.3% of the variance in the SMTP.

Huang et al (8) demonstrated that a multiple model including aerobic power, agility, fat-free mass, strength-endurance and body fat predicted 52% of the variance in the military-specific test. Some of these variables (fat-free mass, strength-endurance and aerobic power) are similar to those included in our model. Using a longer military-specific test, Barringer et al (2) reported that those with higher lower-body muscle power, upper-body strength-endurance and anaerobic capacity were more likely to pass the test compared to those with lower values. It is probable that the differences between the test used in the present study and that used by Barringer et al (2) may explain the distinct predictive variables found in each study. Pihlainen et al (15) used the same test as that used in our investigation and found similar results. These authors reported that 66% of the variance in the SMTP was explained by the performance in countermovement jump, time in a 3000m running test, skeletal muscle mass and push-up repetitions. Although our study did not include a lower-body muscle power performance, the explained SMTP variance was a little higher than that found by these authors. Moreover, the following similarities were observed between the variables included in our predictive model and that reported by Pihlainen et al (15), respectively: free-fat mass and the skeletal muscle mass, the 12-min running test and the 3000m time, and the sit-up repetitions and the push-up repetitions. However, the current study does not report a significant predictive ability of the push-up. Perhaps it is due to only one of the exercises performed in the SMTP is performed with a specific muscle group, when compared to the pushups test. This may have been one of the factors to explain its lack of predictive value.

The fact that the performance in the 12-min running test was the single best predictor of the SMTP and that it was included in the multiple model is related to the higher cardiorespiratory demand of the SMTP and other military-related tasks (6). Future research should determine the physiological responses and energy systems contributions to this test, and to verify if changes in cardiorespiratory fitness affect the SMTP. As the SMTP involves carrying objects and changes of direction, individuals with higher free-fat mass and strength-endurance, especially in the core area, may have an advantage when executing such tasks (15). It was not anticipated that the significant associations of the sit ups and 12-min running would carry the weight of the overall score, which was also correlated with SMTP for been one of the measurements establish in the PCA.

Military occupational specialties may vary widely depending on the military branch. To date, there are some studies available that are specifically targeted to improve these special demands. One of the most studied military tasks is cargo transportation, a highly relevant and necessary task in most military branches, especially in combat units (9). It is noteworthy that there are not many specific motor tests for military. Therefore, due to the limited prediction capacity of the general physical fitness tests, it is necessary to create specific motor tests to the Brazilian military that positively relate to the variables of physiological parameters and to the variables of physical fitness and their respective physical abilities involved. Overall, the combination of endurance and strength training appears to be a superior training method for improving the overall physical performance of soldiers (9). It is highlighted the importance of choosing physical fitness tests that are similar to the operational tasks. According to the study results, considering the SMTP as an important test that evaluates different physical aspects in the operability, four PCA variables had a moderate correlation. However, the results allow us to better understand the possibilities of intervention in military personal and provide an important step in a scarce area of similar work.

There are a few limitations that must be addressed. In the present study, no objective physiological measure was performed (for example, HR, oxygen consumption) and subjective measures (e.g., perceived exertion rate). Future procedures should involve increasing sample size and direct physiological analyzes, such as the use of oxygen consumption analyzers and biochemical analyzes, quantifying the energy demand of the different tests performed. Further, our soldiers' familiarization with the SMTP was limited to only viewing demonstrations of the SMTP as they did not practice the SMTP before testing and the reliability and reproducibility of SMTP were not tested in the present study. In addition to these considerations, it is important to note that procedures that require military-specific skills and additional time to drive (e.g. aiming, hitting a target with a grenade) have been excluded from SMTP. Also, the exclusion of a lower body explosive exercise may have been a limitation, given that previous research has indicated its predictive ability (15). Moreover, considering that the average completion time for the SMTP was around 2 minutes in duration and likely relies on anaerobic energy systems and muscular strength and power capacity of the lower body.

In this study, we find that 12-min running, free-fat mass and sit-up tests were the most significant PCA measurements with moderate accuracy prediction of SMTP performance in active duty soldiers. Therefore, for a better prediction it is necessary to develop specific military simulated tasks according to each branch or replace the current procedures for exercises with more accurate results in order to improve PCA reliability and efficiency. Future research should also focus on the influence of the tests' duration and intensity to predict simulated military task performances, which should also be applied to other military and operational groups. We believe our findings shows that the Physical Conditioning Assessment (PCA) of the Brazilian Air Force needs an improvement for better operational performance prediction, implicating that others PCA for military personnel from auxiliary forces, such as police, fireman, or even other countries Armed Forces, may also need an improvement. Thus, we believe that this opens new perspectives for futures research to focus on the development of new PCA.

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