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Associations of physical fitness and body composition characteristics with simulated military task performance

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ABSTRACT

The purpose of the present study was to evaluate the associations of physical fitness and body composition characteristics with anaerobic endurance performance, tested in the combat load using the occupationally relevant military simulation test (MST). Eighty-one male soldiers, deployed to a crisis management operation in the Middle East, volunteered for the study and participated in a test battery consisting measurements of muscle strength, body composition characteristics, endurance capacity, and MST.

A Spearman correlational analysis revealed that the strongest variable, correlated with MST time, was the countermovement jump performed with the combat load (CMJ2) ($r_s = -0.66, p < 0.001$).

Among the individual body composition variables the MST time had the strongest relationship with fat percentage ($r_s = 0.53, p < 0.001$) and skeletal muscle mass (SMM) ($r_s = -0.47, p < 0.001$). The use of the dead mass ratio, which was calculated dividing body mass by fat mass accompanied with the weight of the combat load, increased body composition-based associations significantly, and this variable turned out to be the best single predictor for the MST performance ($r_s = -0.67, p < 0.001$). Significant predictors of the MST time in the stepwise multivariate regression analysis included CMJ2, 3000m, SMM and push-ups. Together, these variables explained 66 % ($R^2_{adj} = 0.658, model p < 0.001$) of the variance in the MST time.

In conclusion, the novel MST is a promising military specific assessment method of muscle power of the lower extremities as well as endurance capacity which are crucial performance components in anaerobic combat situations.

Keywords: Obstacle course, anaerobic performance, soldier

INTRODUCTION

Military occupations include a variety of demanding tasks that require a certain level of endurance capacity combined with muscular strength^{42, 21, 15}. Commonly these physical fitness components are tested as a part of military recruitment, selection processes or regular follow-up of readiness^{39, 33}. Traditionally, the physical performance of soldiers has been tested by population-based endurance and muscular fitness tests such as a 12-minute running test and push-ups in one or two minutes^{41, 22}. However, army soldiers engaged with combat situations, require an adequate level of anaerobic capacity to perform high-intensity assignments in rapidly changing life-threatening situations. Commonly soldiers are performing such assignments with combat load consisting of a personal weapon, combat gear, protective components and other equipment of the unit^{35, 43}. Such high-intensity tasks typically include sprinting, rushes, climbing, quick changes in movement directions, jumping, crawling, lifting and carrying loads and casualty evacuation³⁵.

Relevance of the basic fitness tests to combat readiness has been questioned in a number of studies, and it has been argued that such health-related fitness tests favor soldiers with low body mass and high relative endurance capacity^{3, 45, 46}. Indeed, most of the basic fitness tests are conducted in light sports clothing and yet, many operational military tasks are often performed wearing combat gear and a body armor which increase the weight of the load carriage²¹. The increase in weight of the carried load influences negatively to the physical performance of soldiers during tasks of longer¹³ and shorter^{26, 28, 19} duration¹¹. Therefore, it can be hypothesized that less body fat^{13, 25} and larger fat free mass²⁵ are beneficial body composition factors in such tasks.

These findings have led to a development of military task related fitness tests that evaluate task specific performance or combat readiness^{38, 44, 37}. Task analysis-based specific tests can be used to improve measurement validity and to study beneficial physical fitness and body composition components in military occupations. Typical occupationally relevant tests include walking or running in various distances in a combat load^{33, 43, 3, 40}, manual material handling³⁸, lifting and carrying loads¹⁰ and obstacle courses^{28, 19} that include mimicking of tactical movements used in combat situations. These simulations include various military-specific test protocols for testing anaerobic capacity and maneuver abilities of soldiers.

The Finnish Defence Forces has hundreds of soldiers serving in several crisis management operations around the world. Despite the fact that the nature of crisis management operations is peacekeeping, and not combat, all soldiers are in a risk of facing hostile actions during their deployment. The most probable scenario in the Middle East would be an attack outside the military camp starting with a road side bomb or other intelligent explosive device and a following fire contact with an enemy group. This scenario would lead to immediate life threatening situation and the actions required for the soldiers to survive would be anaerobic ones from the physiological perspective. However, currently there are no specific field tests for evaluation of anaerobic performance of the crisis management soldiers in Finland. Such test, implemented to a test battery with physical fitness and body composition measurements, would bring new insights to the inter-relationships between the measured variables and thus, could be utilized for development of more optimized physical training programs for soldiers preparing for deployment^{9, 31, 16}. With this in mind, the purpose of the present study was to evaluate the associations of physical fitness and body composition characteristics with simulated high-intensity military task performance.

METHODS

Experimental Approach to the Problem

A novel field expedient military simulation test (MST) was implemented to a test battery of the research project conducted in the Middle East to study the anaerobic performance of soldiers and the interrelationships between MST (dependent variable), physical fitness and body composition variables. The research project lasted six months but the focus of the present study was on the results of the initial measurements. All measurements were conducted during the deployment in a military base in South Lebanon after a two-week acclimatization period. The MST was designed in collaboration with physical training experts and professional soldiers. The test consisted of maneuvers and tasks which might, according to the previously described scenario, be probable in an ambush situation during a patrol or transport in the deployment area. In addition, prior studies focusing on military tasks and simulations were taken into account during the development of MST 17, 26, 28, 31, 32, 42.

Body composition characteristics and strength variables were measured during the first test day. The endurance capacity was tested on the second and MST on the third test day. A minimum of one day for recovery separated the test days. Acute responses of the MST performance were examined to estimate the stress level of soldiers induced by MST. A cross-sectional correlational design and stepwise multivariate regression analyses were used to investigate the relationships between selected body composition and physical fitness parameters, and MST time.

Subjects

More than 250 soldiers were deployed for 6 months in the crisis management operation in the Middle East, and 81 male soldiers without physical limitations took voluntarily part in the present study. Before the deployment, the soldiers were examined by a physician. The mean \pm SD (range) age, height, weight, body mass and body mass index (BMI) of the soldiers were 29.8 \pm 8.0 (20.4–51.2) yrs, 179.8 \pm 6.3 (166.3–199.2) cm, 79.2 \pm 8.5 (58.5–105.6) kg, and 24.5 \pm 2.3 (18.5–31.0) kg·m², respectively. The study was approved by and conducted in accordance to the statement of the Ethical Committee of the Central Finland Health Care District. The soldiers were informed of the benefits and risks of the investigation prior to signing an institutionally approved informed consent document to participate in the study.

Procedures

All measurements were carried out after a two-week acclimatization period inside the military base in South-Lebanon. The clothing conditions were light underwear in the body composition measurements and shorts, T-shirt and indoor or running shoes in the strength and endurance performance measurements.

The measurements of body composition characteristics were conducted in the morning after an overnight fast at a military hospital. Body height was measured by using a wall-mounted height board (Seca Bodymeter 206, Seca GmbH & Co, Hamburg, Germany). Body mass (BM), skeletal muscle mass (SMM), fat mass (FATM) and fat percentage (FAT%) were determined by using the segmental multi-frequency bioimpedance analysis assessment (InBody 720, Biospace Co Ltd, Seoul, South Korea) in accordance with the manufacturer's guidelines.

Dead mass ratio (DMR), adopted from Lyons et al³⁰ was calculated dividing BM by FATM accompanied with the weight of the carried combat load. In the original study by Lyons et al³⁰, DMR was calculated from lean body mass but in the present study from BM as follows:

Dead mass (DM, kg) = FATM + weight of the combat load, excluding assault rifle

$$\text{Dead Mass Ratio (DMR)} = \frac{BM}{DM}$$

Maximal isometric force of the lower (MVC_{lower}) and upper (MVC_{upper}) extremities' extensor muscles were measured bilaterally in a sitting position by using electromechanical dynamometer¹⁸ (University of Jyväskylä, Jyväskylä, Finland) modified from a David 210 dynamometer (David Fitness and Medical, Helsinki, Finland). In the lower extremity measurement, the seat was adjusted to maintain knee and hip angles of 107° and 110°, respectively. In the upper extremity measurement, the handle bar was adjusted to the height of shoulders and seat to maintain elbow angle of 90°. In both tests, the soldiers were instructed to exert their maximal force in all three trials which were separated by a minimum of 30 seconds for recovery. The best performances with regard to maximal force output in both tests were selected for further analysis.

Standing long jump (SLJ) was used to assess explosive force production of the lower extremities⁸. Before the minimum of three test attempts, the soldiers were instructed a proper technique and five to seven warm-up trials were provided. The jumps were performed on a 10-millimeter-thick plastic mattress designed for the purpose (Fysioline Co, Tampere, Finland). The jumps were performed from a standing position, feet at pelvis to shoulder width. Explosive bilateral take off was assisted by powerful extension of the hip and swinging of the arms. The landing was performed bilaterally

and falling backwards led to disqualification of the attempt. The result of the best jump was expressed as centimeters of the shortest distance from the landing point to the starting line.

The dynamic muscle endurance capacity of trunk and upper extremities were assessed by using sit-up, push-up and pull-up tests, respectively. A test supervisor showed the correct technique for each performance before each test. The soldiers were also informed that after a notice from the supervisor incorrect repetitions would not be calculated to the test result.

Sit-ups were used to measure performance of abdominal and hip flexor muscles⁴⁷. In the starting position, the soldier laid on his back while legs were supported from the ankles by an assistant. The knees were flexed at the angle of 90°, elbows pointing upwards and fingers crossed behind the back of the head. One successful repetition was determined when the soldier lifted his upper body from the starting position and brought elbows to the knee-level. The result of the test was expressed as a number of consecutive successful repetitions during 60 seconds.

The push-up test was to measure performance of arm and shoulder extensor muscles¹. Before taking a starting position, the soldier laid face down on the floor, feet parallel at pelvis to shoulder width and hands positioned so that thumbs could reach the shoulders while other fingers pointing forward. Before the initiation of the test, the soldiers were instructed to extend their arms to the starting position and keep the feet, trunk and the shoulders in the same line throughout the test. One successful repetition was counted when the soldier lowered his torso by flexing arms to an elbow

angle of 90° and returned to the starting position by extending his arms. The result of the push-up test was expressed as a number of consecutive successful repetitions during 60 seconds.

The pull-up test was used in order to measure the performance of arm and shoulder flexor muscles. In the starting position, the soldiers hang by their hands from a horizontal bar, arms and feet straight. The underhand grip was instructed to be at shoulder width, and the hip and legs to be extended throughout the test. One successful repetition was performed when the body was raised by flexing arms from the starting position until the chin was above the bar. The result of the test was expressed as a number of consecutive pull-ups until volitional exhaustion.

Endurance performance was evaluated by using the 3000-meter running test. The test was performed on a standardized 1.13-km track covered with asphalt. The total ascent and descent of the track was 32 meters. The soldiers were instructed to complete the test with their maximal effort and in the shortest possible time. The duration of performance was recorded with a stopwatch and heart rate (HR) was recorded throughout the test by the memory belt (Memory belt, Suunto, Vantaa, Finland). Peak heart rate (HR_{peak}) was determined by a computer analysis software (Firstbeat PRO, Firstbeat Technologies, Jyväskylä, Finland) as the highest recorded HR during 3000 m.

MST consisted of typical army soldier maneuvers and tasks. The test was performed on an artificial grass court wearing a combat dress uniform, leather boots and combat gear including a body armor, helmet and assault rifle replica (3 kg). From the starting position of lying supine, the soldiers performed four consecutive 6.2 m rushes changing direction after each rush. After the last rush the soldiers continued 11.3 meters by low crawl, followed by a sprint of 21.8 m. After the sprint, the

soldiers ran another 21.8 m jumping over three 40 cm obstacles (Movemakers Step, Movemakers, Tiistenjoki, Finland) separated by a distance of 5 m. Thereafter, the soldiers lifted, carried and lowered two 16 kg kettlebells (Eleiko Co, Halmstad, Sweden) 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 the soldiers dragged a 65 kg mannequin (Ultimate sandbag, Ultimate sandbag training, Scottsdale, AZ, USA; two sandbags, attached to each other with cable ties) for a circle of 24 meters. The total length of the MST track was 242.5 meters (figure 1A and B).

Figure 1A and B about here, please

Preceding MST, a saliva sample was obtained from all soldiers by using cotton swab according to the manufacturer's guidelines (Salivette, Sarstedt, Nümbrecht, Germany), and blood lactate (BLa) was measured from the fingertip (Accutrend Plus, Roche Diagnostics GmbH, Mannheim, Germany) from 59 randomly selected soldiers. Thereafter, the soldiers rated their perceived exertion (RPE)⁷ and performed three countermovement jumps (CMJ) on a force platform (FP8, HUR Labs, Oulu, Finland) both in their underwear (boxers, t-shirt and socks; CMJ1) and in the combat load excluding the rifle replica (uniform, boots, helmet, body armor, modular vest; CMJ2). The soldiers were allowed 30 s for recovery between the jumps in both clothing conditions. CMJ data were automatically transported to a computer software (Force Platform Software Suite, HUR Labs, Oulu, Finland), and jump height was calculated from the take-off velocity.

Before the MST performance, each soldier was individually familiarized with the track by a supervisor who also gave verbal instructions during the test. The soldiers were instructed to

complete the track in a shortest possible time. The performance time was recorded by a stopwatch and HR by a memory belt (Memory belt, Suunto, Vantaa, Finland).

RPE and saliva sampling were repeated within one minute after the termination of MST.

Immediately after giving the saliva sample, the soldiers performed another three CMJs in the combat load excluding the assault rifle replica (CMJ3). Finally, BLa was obtained 5 minutes after the test.

The saliva samples were stored at -20°C until they were transported in a frozen state for further analysis. The samples were thawed and centrifuged at 3500 rpm for 10 min. Saliva cortisol (saCOR) and alpha-amylase (saAA), as potential non-invasive biomarkers of exercise-induced stress⁶, were analyzed. SaCOR was analyzed by Immulite 2000 XPi (Siemens Healthcare, Llanberies, UK) using chemiluminescent enzyme immunoassay kits, while saAA assays were performed by Konelab 20XTi (Thermo Fisher Scientific, Vantaa, Finland) using the enzyme photometric measurement method (inter-assay CV 13.2% and 3.2%, respectively).

Statistical analyses

Commercial software (IBM SPSS 22.0.0.0, Chicago, Illinois, USA) was used for statistical analyses. Descriptive statistical methods were used for the calculation of means and standard deviations (SD). Significance of the relative differences between variables measured prior to and post- MST were analyzed by using One-Sample Wilcoxon Signed Rank Test, due no non-normality and outliers.

The associations between MST and other measured variables were tested for linearity with Spearman's product moment correlation coefficients. Stepwise multivariate regression analyses were used to model log-transformed MST. The $p < 0.05$ was used to establish statistical significance. Post hoc power for high correlation ($n=81$, $r=0.5$) was 0.998, and for moderate correlation ($n=81$, $r=0.3$) 0.781.

RESULTS

The mean (\pm SD) results of the body composition and physical fitness measurements are presented in table 1.

Table 1 about here, please

The mean (\pm SD) MST performance time was 148 ± 22 s (range 100-214 s, $n=81$). The average HR ($n=64$) during the test was 169 ± 11 bpm (range of means 146-185 bpm) or $90 \pm 4\%$ HR_{peak} (range of means 80-96% HR_{peak}). MST induced three- and fourfold increases in saAA (1 min POST) and BLa (5 min POST), respectively, while saCOR (1 min POST) increased by 12 % from the initial measurement. After the MST, the RPE ratings and BLa levels were 18 ± 1 and 10.8 ± 3.7 mmol·L⁻¹, respectively. The acute PRE-POST responses of the variables are presented in table 2.

Table 2 about here, please

Prior to MST, RPE was rated and CMJ performed twice; in a light underwear and again in the combat load (19.5±1.0 kg). The weight of the combat load increased RPE by 14±22% ($p<0.001$) from 10±2 to 12±2 and reduced the CMJ performance by 25±5 % ($p<0.001$) from 37.8±6.1 to 28.5±5.1 cm. The Spearman correlation analysis showed that the strongest individual predictor of the MST performance was explosive force production of the lower extremities, especially CMJ2 ($r_s = -0.66, p<0.001$) (figure 2).

Figure 2 about here, please

Furthermore, all four variables assessing muscle power of the lower extremities were among the top five strongest associations with MST. In addition, the correlation between CMJ2 and SLJ was high ($r_s = 0.81, p<0.001$). Among individual body composition variables, MST had strongest correlations with FAT% ($r_s = 0.53, p<0.001$) and SMM ($r_s = -0.47, p<0.001$). Body mass ($r_s = -0.18, p=0.10$) or BMI ($r_s = 0.07, p=0.55$) were not associated with the MST time, while the associations with FATM ($r_s = -0.40, p<0.001$) and body height ($r_s = -0.38, p<0.001$) were moderate. The use of DMR increased body composition-based correlations significantly and this variable turned out to be the best predictor of MST performance ($r_s = -0.67, p<0.001$; figure 3). The correlations between the MST time and other measured variables are presented in table 3.

Figure 3 about here, please

Table 3 about here, please

The stepwise regression analysis showed that four variables (CMJ2, 3000m, SMM and push-ups) were significantly associated with the MST time. Together, these variables explained 66 % ($R=0.82$, $R^2_{adj}=0.658$, $F(2.495)=38.531$, $p<0.001$) of the variance in the MST time. CMJ2 independently explained 47 % of the variance in the MST time. The run time in 3000m improved the prediction of the model by 13 % (combined $R^2_{adj} = 0.608$). Significant but minimal improvements were reached by adding SMM (combined $R^2_{adj} = 0.633$) and finally, push-ups (combined $R^2_{adj} = 0.658$) to the prediction model. Together, these variables formed a following MST time prediction model:

$y = 5,201 - 0,011x_1 + 0,001x_2 - 0,008x_3 - 0,002x_4$, where y is MST (s), x_1 is CMJ2 (cm), x_2 is 3000m (s), x_3 is SMM (kg) and x_4 is push-ups (repetitions in minute).

DISCUSSION

The present study demonstrated that the two statistically strongest variables, which were inversely associated with the MST performance, were DMR and CMJ performed in combat load (CMJ2). Furthermore, all variables measuring muscle power of the lower extremities were good predictors for the MST performance. These results are in line with previous studies using job-specific anaerobic task simulations^{35,31,2}. The regression analyses revealed that especially the jump height of CMJ2 and 3000m time but also SMM and 1-min push-up test result were significant predictors of the MST performance. Thus, the presented MST is a promising military specific assessment

method of muscle power of the lower extremities as well as endurance capacity which are important performance components in anaerobic combat situations.

Blood lactate has traditionally been used as a biomarker of exercise intensity but during the last decade, new non-invasive methods to estimate physiological stress during increasing work load have been introduced in a number of studies^{6, 12, 14, 20, 36}. De Oliveira et al¹² found strong associations between BLa and saAA during the incremental exercise test and similar findings have been observed in other studies¹⁴. In the present study, significant increases in RPE, BLa and saAA at the termination of the test indicate that the MST performance was subjectively and physically demanding for the soldiers. However, no associations between acute biomarkers were observed. A moderate but insignificant increase in saCOR was observed after MST. It is possible that the duration of the MST performance was too short to induce acute saCOR responses immediately after the test. Increases in the saCOR has been observed in athletes immediately after but, especially, 30 min after the tests with high intensity endurance exercise lasting 12-15 minutes²⁰ as well as high-intensity exercise lasting 15 minutes³⁶.

Rushing speed has positively been associated with survivability in military simulations^{3, 5}. Mala et al³¹ observed a significant inverse relationship between vertical jump peak power measured by CMJ ($r = -0.66$) and 5-m sprint time in the combat load ($r = -0.66$). Both vertical and horizontal jump performances have also been shown to associate strongly with sprinting speed in elite athletes²⁹. Furthermore, the finding that the strongest predictor of anaerobic military task course performance was CMJ peak power ($r = -0.67$) by Mala et al³¹ is well supported by the present study. Harman et al¹⁷ tested a number of anthropometric measures and fitness tests for prediction

models of physical performance in the battlefield. The vertical jump height entered in all prediction equations of four combat specific tests performed with a fighting load (400-m run time, obstacle course time, five 30-m rushes and a simulated casualty rescue). Based on these findings, it can be concluded that explosive power of the lower extremities is essential in anaerobic combat situations.

It has been established that both anaerobic and aerobic metabolic pathways contribute to continuous, near maximal intensity muscle work exceeding two minutes²³. The association of aerobic capacity and load carriage performance has, however, been found in studies using longer load carriage test protocols^{40, 30}. In the study of Harman et al¹⁷, the second most common variable after the vertical jump, predicting battlefield specific performance was the 3.2-km run which entered three out of the four models, even though the duration of their tests varied between 43 and 84 s. In the present study, the 3000m run time associated significantly with the MST time ($r_s = 0.48, p < 0.001$) and improved the stepwise regression model prediction by 13 %. Based on previous studies, it is likely that with by increasing the length of the MST track would have increased the correlation between the endurance performance and MST.

External load, typically carried by soldiers in the form of the combat gear, has a negative impact on combative movement performance^{3, 32} as well as repeated high-intensity military tasks^{35, 19}. The results of Jaworski et al¹⁹ indicate that increasing the relative weight of the carried load decreases combat-related performance capability. Billing et al³ investigated the effects of increasing load on susceptibility to enemy fire during tactical combat movements. They found that the duration of exposure to enemy fire during the experiment increased linearly with the increase in external load. Another important finding was, that the decline of performance for the faster subjects was 0.8 % per

kg increase in external weight, whereas for the slower subjects the decline was 1.4 % per kg. The only significant difference in the measured body composition characteristics (height, body weight, fat mass, muscle mass) or physical performance (maximal aerobic capacity, upper and lower-body power) variables between the fast and slow performers was higher lower-body power of the fast performers measured by the vertical jump height. These findings are in close coherence with the present study. It is also noteworthy that compared to no load condition the combat load increased discomfort and, more importantly, reduced explosive strength by 25 %, measured by CMJ2 before the actual performance of MST. Furthermore, CMJ2 showed a stronger correlation with DMR ($r_s = -0.73$) than with BM ($r_s = 0.21$), FATM ($r_s = -0.45$) or DM ($r_s = -0.47$) independently.

The present study demonstrated that BM solely is not a good predictor of the MST performance as it was not associated with the MST time. This observation is supported by the study of Bishop et al.⁴ who found that BM explained only a minor part (~6%) of indoor obstacle course completion time. In their study, improved obstacle course performance was more strongly explained by the lower amount of body fat and higher muscle strength, endurance and power relative to BM, but also by technique and agility.

The moderate inverse correlations between SMM and MST ($r_s = -0.47$, $p < 0.001$) as well as between SMM and CMJ2 ($r_s = -0.56$, $p < 0.001$) suggest that higher skeletal muscle mass might improve military specific anaerobic performance. The inclusion of SMM as a significant variable in the stepwise regression model supports this suggestion. On the other hand, the strength of body composition-based correlation was improved by using the DMR equation adopted from Lyons et al.³⁰. In their study, strong correlations were found between metabolic demands (relative oxygen

consumption, %VO₂max) and DMR with increasing external loads in the load carriage test. From the physiological perspective this seems logical. The energy consumption of the working muscles increases in relation to force output which in turn depends on the weight of the carried load in weight bearing movements³⁰. In the present military context, the weight was formed of a combination of fat mass and combat load (=DM). A smaller DM in relation to BM leads to a lower relative energy expenditure and thus, the ability to perform MST in a shorter time. DMR was not, however, included into the regression analysis, probably due to multicollinearity with the other body composition variables.

As in any sports, the focus of military physical training should be success in the given tasks. Therefore, it is important to gain knowledge of the variables of body composition and physical performance behind that success. The present findings suggest that important characteristics of a soldier involved with combat situations are a high level of muscular power in the lower extremities, endurance capacity, large muscle mass in relation to fat mass as well as the external load carried during various assignments. A more detailed basis for optimized strength training prescription for the warfighter has been published by Kraemer and Szivak²⁴.

The present study had some weaknesses that need to be discussed. As in all simulations, the validity, reliability and reproducibility of the test method can be questioned. The reliability and reproducibility of MST were not tested in the present study. The MST track was planned to solely evaluate the anaerobic endurance capacity of soldiers. Thus, procedures requiring specific skills and additional time to conduct (e.g. aiming, hitting a target with a grenade) were excluded from the protocol. Compared to real-life scenario, this may weaken the relevance of the test method.

However, all scenarios are generally theoretical in nature and the selected sub-tasks in the present test model include the most typical movement patterns to soldiers involved with combat⁴³. In addition, this was the first time for the soldiers to perform the MST and, therefore, they have not had possibilities to make, for instance, pacing strategies for their performance based on prior trials. Thus, the associations found in the present study may in fact resemble even more reliable performance predictors of suddenly changing real-life scenarios than during repeated trials.

In conclusion, BM in relation to FATM and the carried load as well as muscular power of the lower extremities seem to be good predictors of high-intensity military performance, measured by MST. Furthermore, workouts focusing on development of lower body strength and power are encouraged to be implemented to training programs designed for soldiers engaging anaerobic combat situations. In addition, basic fitness tests such as vertical jump, 3000-m run, push-ups and SMM seem to be reliable and time saving methods to assess military performance of soldiers.

PRACTICAL APPLICATIONS

The present study introduced a novel, field-expedient MST which can be utilized to estimate the high intensity anaerobic performance capacity of soldiers. The MST track can be built with minimal space and equipment requirements (Fig 1B). Previous studies have proven the utility of simple jump tests to detect performance decrements induced by intensive military training^{34, 48}. In the present study, SLJ produced nearly similar correlations as CMJ2 did with the MST time. In addition, the correlation between CMJ2 and SLJ was high. Therefore, the standing long jump could be one good possibility as a simple, field-expedient test to evaluate military relevant high-intensity task performance of soldiers, even during military operations. Furthermore, physical training specialists

should implement workouts focusing on development of the lower body strength and power alongside with aerobic endurance. The main aim of such training programs is to improve physical performance in anaerobic combat situations.

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TABLES

Table 1. Mean (\pm SD and range) values of the body composition and physical fitness variables of the soldiers.

| Variable | Mean | SD | Min | Max | <i>n</i> |
|--------------------------|------|-----|------|------|----------|
| SMM (kg) | 39.1 | 4.3 | 30.0 | 49.2 | 81 |
| FATM (kg) | 11.0 | 4.8 | 2.9 | 31.5 | 81 |
| FAT% | 13.7 | 5.0 | 3.6 | 31.5 | 81 |
| MVC _{lower} (N) | 4238 | 922 | 2246 | 6563 | 81 |
| MVC _{upper} (N) | 1139 | 227 | 716 | 1736 | 81 |
| SLJ (cm) | 235 | 24 | 174 | 300 | 80 |
| CMJ1 (cm) | 38 | 6 | 23 | 54 | 81 |
| Sit-ups (reps/min) | 46 | 10 | 20 | 64 | 81 |
| Push-ups (reps/min) | 41 | 13 | 10 | 78 | 81 |
| Pull-ups (rep max) | 10 | 5 | 0 | 20 | 81 |
| 3000 m run (s) | 835 | 87 | 636 | 1106 | 81 |

SMM, skeletal muscle mass; FATM, fat mass; MVC_{lower}, maximal voluntary contraction of the lower extremities; MVC_{upper}, maximal voluntary contraction of the upper extremities; SLJ, standing long jump; CMJ, counter movement jump.

Table 2. Mean (\pm SD) acute changes in saAA, saCOR, RPE, BLa and CMJ induced by MST.

| Variable | Pre | Post | % change | <i>p</i> | <i>n</i> |
|----------------|----------------|----------------|---------------|----------|----------|
| saAA (U·mL) | 66 \pm 66 | 179 \pm 166 | 306 \pm 321 | <0.001 | 68 |
| saCOR (nmol·L) | 13.9 \pm 6.2 | 14.9 \pm 6.8 | 12 \pm 49 | 0.332 | 65 |
| RPE (6-20)* | 12 \pm 2 | 18 \pm 1 | 81 \pm 42 | <0.001 | 81 |
| BLa (mmol·L) | 2.6 \pm 1.5 | 10.8 \pm 3.7 | 414 \pm 294 | <0.001 | 57 |
| CMJ (cm)** | 28.5 \pm 5.1 | 27.0 \pm 5.0 | -5 \pm 9 | <0.001 | 81 |

saAA, saliva alpha-amylase; saCOR, saliva cortisol; RPE, rating of perceived exertion; BLa, blood lactate; CMJ, countermovement jump; MST, military simulation test. *, both RPE values estimated in combat load; **, both jumps performed in combat load.

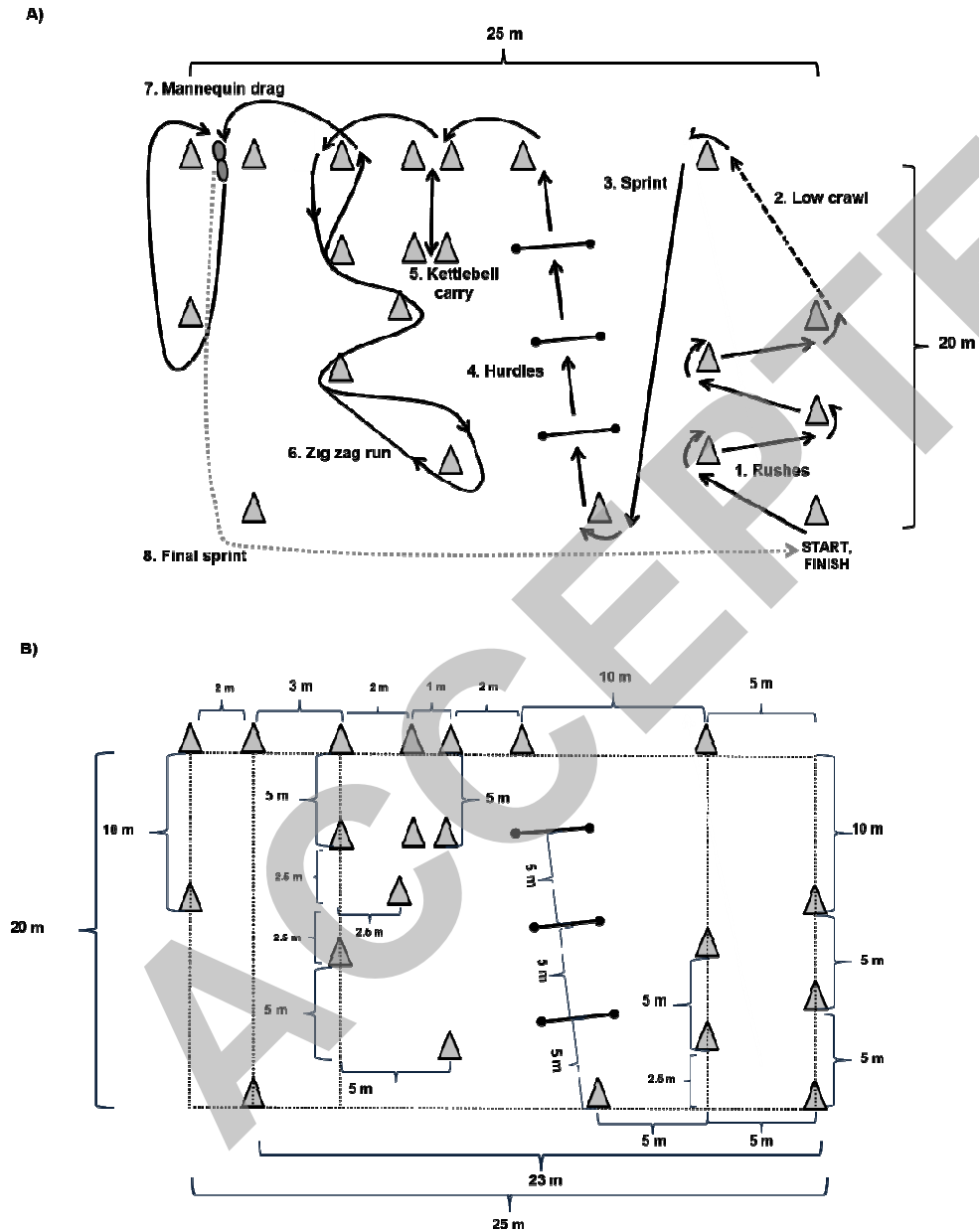
Table 3. Associations between the measured variables and MST.

| Variable | r_s | p | n |
|--------------------------|--------|--------|-----|
| DMR (kg) | -0.669 | <0.001 | 81 |
| CMJ2 (cm) | -0.659 | <0.001 | 81 |
| SLJ (cm) | -0.616 | <0.001 | 80 |
| CMJ3 (cm) | -0.614 | <0.001 | 81 |
| CMJ1 (cm) | -0.595 | <0.001 | 81 |
| Sit-ups (reps/min) | -0.546 | <0.001 | 81 |
| FAT% | -0.534 | <0.001 | 81 |
| Push-ups (reps/min) | -0.533 | <0.001 | 81 |
| MVC _{upper} (N) | -0.485 | <0.001 | 81 |
| 3000 m run (s) | 0.483 | <0.001 | 81 |
| SMM (kg) | -0.474 | <0.001 | 81 |
| MVC _{lower} (N) | -0.454 | <0.001 | 81 |
| Pull-ups (rep max) | -0.435 | <0.001 | 81 |
| DW (kg) | 0.427 | <0.001 | 81 |
| FATM (kg) | 0.403 | <0.001 | 81 |
| Body height (cm) | -0.384 | <0.001 | 81 |
| BM (kg) | -0.183 | n.s. | 81 |

DMR, dead mass ratio; BM, body mass; CMJ, counter movement jump; SLJ, standing long jump; MVC_{upper}, maximal voluntary contraction of the upper extremities; SMM, skeletal muscle mass; MVC_{lower}, maximal voluntary contraction of the lower extremities; DM, dead mass; FATM, fat mass; BM, body mass.

FIGURES

Figure 1. Schematic illustration (A) and technical graph (B) of the military simulation test (MST) track.



MST equipment: 20 plastic cones; 3 hurdles, height 40 cm/hurdle; 4 kettlebells, weight 16 kg/kettlebell; mannequin, total weight 65 kg; tape measure, 25 m.

Figure 2. Countermovement jump height, performed with a combat load excluding the assault rifle replica (CMJ2), plotted against military simulation test (MST) time.

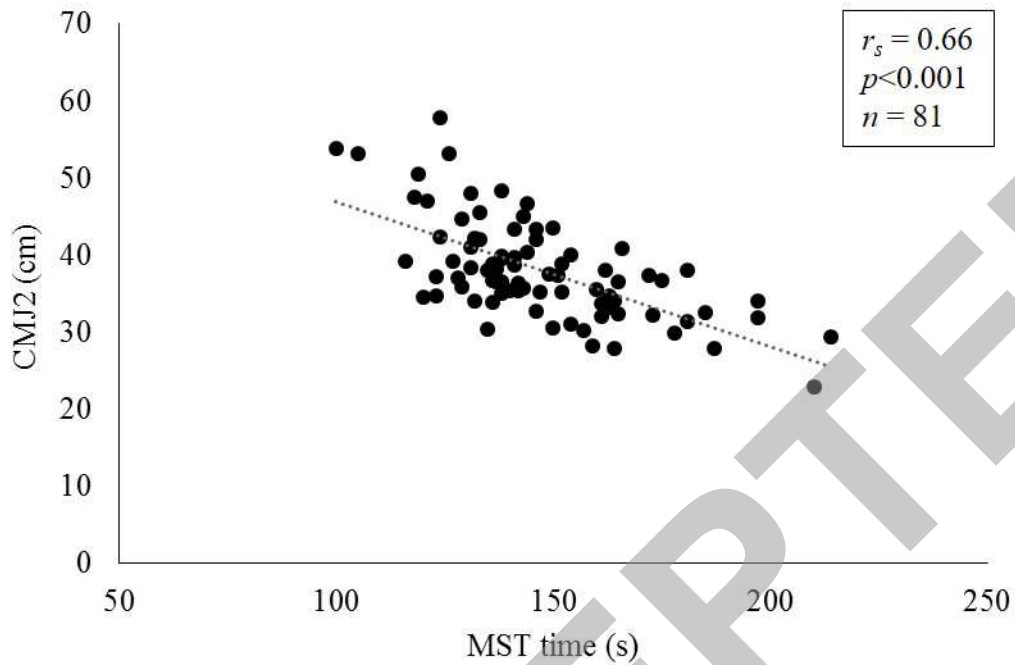


Figure 3. Dead mass ratio (DMR) plotted against the military simulation test (MST) time.

