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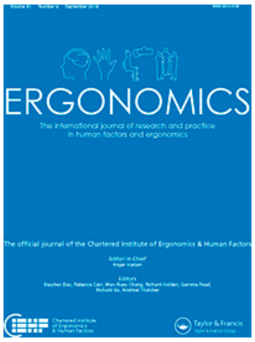

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Performance changes during repeated military occupational test and its associations to physical performance

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Keywords: soldier, combat readiness, task performance

ABSTRACT

The present study investigated performance changes during three runs (1 min recovery) of repeated military simulation task test (RMST) and its associations with physical performance. Voluntary male soldiers (N=114) participated in a series of measurements of physical performance. Lower body explosive force production, anaerobic endurance and upper body strength endurance together explained 58% of the variance in the first RSMT (p<0.001). The same variables explained the variance in the second and third runs of RSMT by 60% and 51%, but explosive force production was replaced with aerobic endurance, assessed by the 3.2 km loaded run (p<0.001). This study demonstrated that the role of explosive power of the lower body decreased and military specific aerobic endurance increased when occupational performance was assessed under acute fatigue even during a short high-intensity test. These results may benefit tactical strength and conditioning coaches in training optimization for improved occupational performance in military.

PRACTIONERS SUMMARY

Soldiers are required to perform occupational tasks in a repeated manner with short recovery time. In the present study, the role of explosive power of the lower body decreased and military specific aerobic endurance increased when occupational performance was assessed with a repeated high-intensity task specific performance test.

INTRODUCTION

During military training soldiers are prepared for demanding combat duties. Previous studies have reported that many common military tasks, including lifting, carrying and lowering of loads, casualty evacuation and movement under enemy fire are physically and mentally demanding, requiring significant neuromuscular and cardiorespiratory performance (Vaara et al., 2021). Furthermore, soldiers typically carry combat gear including body armor and personal as well as group equipment, which in terms of mobility and power production reduces the occupational performance (Billing et al. 2015, Drain et al. 2016, Joseph et al. 2018). Therefore, it is assumed that military specific training and exercises may enhance combat readiness of soldiers.

Optimization of combat readiness in soldiers by means of physical training requires determination of essential physical fitness components (Kyröläinen et al. 2018). Associations of military simulations with neuromuscular and endurance performance variables have been studied extensively during the last few decades (Hauschild et al. 2017, Vaara et al. 2021). Knowledge of operationally relevant physical characteristics support the development of physical training that transfers to more efficient occupational performance. The role of body composition is also important in weight-bearing military tasks, as it has been shown in several studies that excess body fat has negative impact on performance both with (Pihlainen et al. 2018) and without body armor (Lyons et al. 2005). Several studies have documented that explosive and maximal force production of the lower body is associated with combat tasks such as rushes or casualty evacuation (Mala et al. 2015, Blount et al. 2013, Nindl et al. 2015, Stein et al. 2022, Poser et al. 2019). A review by Hauschild et al. (2017) reported that muscular strength is more strongly associated with single, high-intensity tasks, whereas aerobic capacity correlates more with lower intensity repeated tasks. Higher muscle mass can also enhance military specific performance (Crawford et al. 2011, Pihlainen et al. 2018). One of the weaknesses of the earlier studies (Angelveit et al. 2016, Mala et al. 2015, Pihlainen et al. 2018) is the non-repetitive nature of the reference (e.g. military) task. It is important to note that many combat tasks (e.g. short sprints, manual material handling, load carriage) are performed in a repeated manner and recovery time between the tasks may be inadequate (Billing et al. 2015). During intensive combat this may lead to fatigue and increase susceptibility to enemy fire (Billing et al. 2015, Stein et al. 2022). Therefore, it is important to study physical fitness variables and repeated military tasks to observe possible changes between their associations.

While previous studies have reported fitness predictors for a military simulation or individual tasks performed in a recovered state, the present study focused on changes in physical performance during repeated military simulation test and its associations to various components of physical performance.

MATERIALS AND METHODS

Subjects

A group of 114 male soldiers volunteered to participate in the study. The mean ± *SD* (range) age, height, body mass (BM), and body mass index (BMI) of the soldiers were 20 ± 1 (18-22) years, 180 ± 6 (167-197) cm, 72.4 ± 9.1 (55.1 - 104.6) kg, and 22.3 ± 2.3 (17.4-30.1) kg/m². The subjects were all from the same infantry company mid-way on their conscript service. The present study was conducted according to the provisions of the Declaration on Helsinki and was granted an ethical approval form the Ethical Committee of the University of Jyväskylä. The study was approved by the Finnish Defence Forces (AM743). All subjects were informed of the experimental design, and the benefits and possible risks that could be associated with the study prior to signing an informed consent to voluntary participate in the study.

Experimental design and procedures

A new advanced repeated simulated military task performance test (RSMT) was constructed in a joint effort with strength and conditioning specialists and professional soldiers to study interrelationships between RSMT, body composition, and physical fitness (Ojanen et al. 2020, Ojanen 2022). RSMT contained typical combat tasks and maneuvers, including sprinting, crawling, load carriage, and casualty evacuation. Previous studies on military tasks and simulations were considered when developing RSMT (Harman et al. 2008, Laing-Treloar et al. 2011, Larsen et al. 2012, Mala et al. 2015, Pihlainen et al. 2018).

Participants performed the strength and power tests in a same order and on a same day between 08:00 – 11:00 and RSMT on afternoon between 13:00 – 16:00. The 3.2 km loaded run was performed on a separate day with at least 24-hour recovery after the strength and power tests. The subjects were verbally motivated by instructor to reach their maximum effort in each test.

Measures

Body composition

Body composition was measured in the morning after an overnight fast and before breakfast. Body mass (BM), fat mass (FM), skeletal muscle mass (SMM), and fat percentage (FAT%) were determined using the segmental multifrequency bioimpedance analysis assessment (InBody 720 / 770, Biospace Co. Ltd., Seoul, South Korea) in accordance with the manufacturer´s guidelines. Dead mass ratio (DMR) was calculated according to Lyons et al. (2005) by dividing BM by FM along with the weight of the carried combat gear.

Military task performance

Repeated Simulated Military Task Performance (RSMT) was performed indoors on an artificial turf. The soldiers were wearing normal combat gear, excluding their assault rifle (total weight of 22 kg). RSMT started from supine position with a 10 m sprint, followed by a 10 m low crawl. Thereafter, the soldiers carried and lowered two 16-kg kettlebells (CompactFit Ltd., Helsinki, Finland) twice for a distance on 10 m while going down to a supine position when lowering the kettlebells to the ground. Carrying task was followed by casualty evacuation, which was performed by a 75-kg sandbag drag (Rogue Sandbag, Rogue Fitness Europe Ltd., Pori, Finland) for 10 m. Finally, RSMT ended with a 10 m sprint. The total length of the track was 60 m (Ojanen et al. 2020, Ojanen 2022).

RSMT was performed three times with a 60-second recovery between the runs to simulate repeated nature of tasks in the battlefield environment. A physical instructor, individually familiarized all participants with the tasks and track before the actual timed run. In addition, the soldiers were very familiar with the individual tasks of RSMT, since the participants were performing their 9-week specialized military training phase, which follows the 8-week basic training period. The time was recorded with a stopwatch and afterwards, the occupational task times were determined by using video analysis with an accuracy of 0.1 seconds. Peak heart rate was recorded from each run (Firstbeat Team, Firstbeat Technologies, Jyväskylä, Finland), and blood lactate sample was taken from the fingertip (20µL) five times (before, after each trial, and 10 min after the final trial) and analyzed (Biosen c-line Sport, EKF Diagnostic, Madgeburg, Germany). The sensitivity for lactate analysis was 0.5 mmol/L and interassay coefficient of variation was 6.2%.

In addition, the soldiers shot 10 rounds from a prone position before and immediately after performing RSMT with an assault rifle replica (RK95, Finland). Total sum of 10 shots, recorded from the electronic software system (Eko-Aims Ltd., Ylämylly, Finland) was utilized for further analysis.

Maximal isometric force

Maximal isometric force of the upper (MVC_{upper}) and lower (MVC_{lower}) extremities was measured in a sitting position by using an electromechanical dynamometer (Häkkinen et al. 1998) (University of Jyväskylä, Jyväskylä, Finland). When measuring isometric force of the upper extremities, the pushing bar was adjusted to the height of the subjects' shoulders and the distance of the seat was set to maintain an elbow angle of 90°. For isometric force measurements of the lower extremities, the seat was adjusted to maintain knee and hip angles of 107° and 110°, respectively. Each subject had two warm-up trials and two actual measurement trials in both upper and lower extremity tests, separated by a minimum of 30 seconds for recovery. The subjects were instructed to push the bar / pedals as fast as possible after a start command for 3 to 4 seconds. The peak force output from both tests were selected for further analysis.

Explosive strength

Countermovement jump (CMJ) and standing long jump (SLJ) were measured to assess explosive force production of the lower extremities (Bosco et al. 1983). CMJ was performed on a contact mat (Newtest Ltd., Oulu, Finland) for measuring a flight time of the center of gravity of the subject. It was used to calculate the jumping height for each attempt. The participants held their hands on their hips during the whole jump. SLJ was performed on a 10-mm thick plastic mattress designed for the purpose (Fysioline Co., Tampere, Finland). Both tests were performed from a standing position, feet at pelvis to shoulder width. In both tests, the subjects were given two practice jumps before the actual three test jumps. Participants were allowed to have a minimum of 30-second recovery between the attempts and the longest jumps were selected for further analysis.

Cycle ergometer (Wattbike Ltd., Nottingham, UK) was used to measure average and maximal anaerobic power of the lower extremities during a six-second all out test (Herbert et al. 2015). The test has a seated stationary start with a dominant leg initiating the first down-stroke. The test starts with five-second countdown followed by verbal command. In addition, the completion of the test was indicated with verbal command. Average and maximal anaerobic power outputs (W) were recorded by the ergometer software and selected for the statistical analysis.

Sit-ups and push-ups

Strength endurance of the upper extremities and trunk muscles was assessed using one-minute push-up and sit-up tests. Proper technique for both performances was shown before the tests. Sit-ups were used to evaluate performance of the abdominal and hip flexor muscles (Viljanen et al. 1991). In the starting position, the subjects laid on their back, elbows pointing upwards and fingers crossed behind the head. Knee angle was 90°, and an assistant supported the legs from the ankles. A successful repetition was established when the upper body was lifted from the starting position and the elbows touched the knees. The number of consecutive successful repetitions during one minute was used for statistical analyses. Push-up test was conducted after a five-minute recovery period for the sit-up test to evaluate performance of the arm and shoulder extensor muscles (ACSM 2000). Before the launch of the test, the subjects were instructed to extend their arms to the starting position and keep hip, trunk, and shoulders in the same line throughout the test. Successful repetition was accepted when the subject lowered his torso by flexing arms to an elbow angle of 90°, and returned to the starting position by extending his arms. The result was the number of successful repetitions during one-minute time.

Endurance

To evaluate endurance performance, a 12-minute running test (Cooper, 1968), and a 3.2 km loaded run (Kraemer et al. 2004, Santtila et al. 2010) were performed. The 12-minute running test was performed on a 400-m track. The 3.2 km loaded run was performed for all participants at the same time on a gravel road with 25 kg of combat load, including personal assault rifle. The personal equipment was checked before the actual run to make sure that everyone was carrying the same combat load. The subjects were instructed in both tests to complete the test with maximal effort and in the shortest possible time. The distance in 12-minutes test was measured with an accuracy of 5 meters, and the time in 3.2 km march with an accuracy of 1 second.

Statistical analysis

Statistical analysis were conducted in R v 4.1.2 (R Core Team, 2021). All data were checked quantitatively and visually for normality and logarithmic transformation were performed for skewed, not-normal variables. Data are presented as means with standard deviation and confidence intervals (95% CI) when appropriate. Repeated measures analysis of variance was performed for inspecting dependency between logarithmically transformed performance time and trials (log-performance time and sub-trials). Variances were unequal within trial (sub-trial) groups, therefore pairwise comparisons were performed with Welch’s test for every log-performance time for total trial, and sub-trials (crawl, kettlebell carry, evacuation) and p-values were corrected with Benjamin-Hochberg correction for multiple comparisons testing. All data were examined quantitively and graphically. Explanatory variables were not-normally distributed; therefore, Spearman’s r rank correlation coefficient was used for all calculations between log-performance times and explanatory variables (0.0-0.2 as a very weak, 0.2-0.4 as a weak, 0.4-0.6 as a moderate, 0.6-0.8 as a strong, and 0.8-1.0 as a very strong).

Standard multiple regression was used to find the model which best explained the variance in performance time in the RMST with backward stepwise variable selection by minimizing Akaike's and Schwarz's (Bayesian) information criteria, inspecting explained variability (R^2) and significance of the regression model was tested with F-test. The dependent variables were logarithmically transformed overall total performance time in all three tests, total performance time in every test (1,2 and 3) and partial performance time for crawling, kettlebell carry and evacuation (drag) out of each test. Also, changes between measurement times are examined by modeling percentage differences between time points 1st v 2nd, 1st v 3rd and 2nd v 3rd of performance times. Variables that were used as independent variables in regression were *Push-up, Abdom, Iso_low, Iso_up, Avg_ergo, Max_ergo, SLJ, CMJ_cm, Cooper and Pikamarssi (fast march)*. Variable *Max_ergo* was removed from analysis after multicollinearity check between explanatory variables by variance inflation factor (VIF). The level of significance was set to 95% confidence ($p < 0.05$) and suitability of regression models were verified inspecting residuals.

Therefore, linear regression model has format:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_9 X_9 + \varepsilon,$$

where Y is dependent variable (e.g. log(performance time of first test)), β_0 is constant variable, $X_1, \ldots, X_9$ are dependent variables listed above, $\beta_1, \ldots, \beta_9$ are estimated coefficients, and ε is error term of the model, which is assumed to be normally distributed with expected value of 0 and standard deviation of 1, $\varepsilon \sim N(\mu = 0, \sigma = 1)$.

RESULTS

Body composition and physical performance

The results of body composition as well as neuromuscular and endurance performance tests are shown in table 1.

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

	Mean	SD	Min	Max	n
BM (kg)	72.4	9.1	55.1	104.6	114
SMM (kg)	35.8	4.1	27.4	46.0	114
FM (kg)	9.3	4.5	2.0	23.5	114
FAT %	12.5	5.0	3.0	24.9	114
MVC_{lower} (N)	2398	555	1471	4207	114
MVC_{upper} (N)	739	150	412	1108	113
CMJ (cm)	30.6	5.2	20	47	114
SLJ (cm)	219.4	23.4	150	290	114
$Power_{ave}$ (W)	920	134	639	1318	114
$Power_{max}$ (W)	1027	151	830	2080	114
Sit-ups (reps·min^{-1})	41	9	18	60	114
Push-ups (reps·min^{-1})	35	13	10	64	113
12-min run (m)	2673	330	1345	3368	111
3.2 km Loaded run (s)	1227	250	830	2080	112

BM = body mass; SMM = skeletal muscle mass; FM = fat mass; MVC_{lower} = maximal voluntary contraction of the lower extremities; MVC_{upper} = maximal voluntary contraction of the upper extremities; CMJ = countermovement jump; SJL = standing long jump; $Power_{ave}$ = average power of 6 second cycle ergometer; $Power_{max}$ = maximal power of 6 second cycle ergometer

Repeated Simulated Military Task (RSMT) Performance

RSMT performance total time and different task times for the three runs are shown in Table 2. The total time increased 19% ($p<0.01$) between the first and second run and 34% ($p<0.01$) between the first and third run. Similar increases were also observed in crawling (18%, $p<0.01$ and 40%, $p<0.01$), load carriage (15%, $p<0.01$ and 26%, $p<0.01$), and evacuation (30%, $p<0.01$ and 48%, $p<0.01$). The mean ± SD lactate value was 3.7±1.5 mmol/L after the first run of RSMT. Lactate values increased to 8.9±2.4 mmol/L ($p<0.01$) after the second run, and to 12.9±2.5 mmol/L (p<0.01) after the third run. The shooting score declined by 6.1% after RSMT when compared to shooting performed before RSMT (93.2±8.1 points vs. 87.5±11.5 points, p<0.01).

Table 2. Mean (±*SD* and range) and 95% confidence interval (CI) values of the total and different task split times of RSMT.

Variable		**Mean**	**SD**	**Min**	**Max**	**CI95**	**n**
Total time (s)	1st run	36.0	5.6	25.4	55.2	(35.9 ; 37.9)	114
	2nd run	44.0*	8.7	29.5	80.1	(42.4 ; 45.6)	114
	3rd run	49.6*,#	12.1	30.8	108.4	(47.3 ; 51.8)	114
Crawling (s)	1st run	7.5	1.5	4.5	12.3	(7.2 ; 7.8)	114
	2nd run	8.8*	2.0	4.6	15.9	(8.5 ; 9.2)	114
	3rd run	10.5*,#	2.8	5.6	19.9	(10.0 ; 11.0)	114
Load carriage (s)	1st run	11.6	1.4	8.3	16.3	(11.3 ; 11.9)	114
	2nd run	13.3*	2.1	8.8	21.9	(12.9 ; 13.7)	114
	3rd run	14.6*,#	2.7	10.2	26.1	(14.1 ; 15.1)	114
Evacuation (s)	1st run	11.1	2.8	6.7	20.7	(10.6 ; 11:6)	114
	2nd run	14.4*	5.0	7.6	37.8	(13:5 ; 15.3)	114
	3rd run	16.5*,#	6.8	8.8	56.0	(15.2 ; 17.7)	114

* = compared to 1st run values *=p<0.01; # = compared to 2nd run values, #=p<0.01

Associations between physical performance tests and RSMT

There were significant negative correlations between the physical performance test results and the run times for RSMT. Regarding the relationships between the neuromuscular tests and the total RSMT time, moderate to strong inverse correlations (r=-0.57 - -0.66, p<0.05) were found for maximal and average power for the first, second, and third run, respectively. In addition, moderate inverse correlations were observed between RSMT times and isometric force production of the upper and lower body (r=-0.49 - -0.59, p<0.05). RSMT also correlated moderately with SLJ and push-up test performances (r=-0.51 - -0.59, p<0.05). Correlations between 3.2 km loaded run and RSMT were moderate, and higher for the second (r=0.58, p<0.05) and third run (r=0.56, p<0.05) when compared to the first run (r=0.43, p<0.05). When looking at the different tasks of RSMT, similar findings were found (Table 3).

Table 3. Correlations between neuromuscular tests and RSMT and task split times. All marked correlations are statistically significant ($p<0.05$)

	1st run				2nd run				3rd run			
Variable	**Total**	**Crawl**	**KB carry**	**Evac**	**Total**	**Crawl**	**KB carry**	**Evac**	**Total**	**Crawl**	**KB carry**	**Evac**
3.2 km march	0.43	0.21	0.32	0.45	0.58	0.37	0.52	0.54	0.56	0.41	0.53	0.51
Cooper test	-0.41	-0.25	-0.36	-0.36	-0.49	-0.38	-0.46	-0.40	-0.45	-0.37	-0.48	-0.38
CMJ	-0.45	-0.41	-0.43	-0.38	-0.38	-0.37	-0.39	-0.30	-0.34	-0.34	-0.37	-0.28
SLJ	-0.59	-0.43	-0.53	-0.54	-0.56	-0.48	-0.54	-0.48	-0.52	-0.44	-0.49	-0.43
Power$_{max}$	-0.66	-0.39	-0.57	-0.69	-0.60	-0.37	-0.58	-0.61	-0.58	-0.33	-0.53	-0.59
Power$_{ave}$	-0.63	-0.35	-0.53	-0.69	-0.61	-0.35	-0.59	-0.62	-0.57	-0.29	-0.52	-0.61
MVC$_{lower}$	-0.59	-0.43	-0.54	-0.54	-0.55	-0.42	-0.55	-0.47	-0.53	-0.35	-0.50	-0.48
MVC$_{upper}$	-0.53	-0.40	-0.47	-0.47	-0.52	-0.44	-0.46	-0.47	-0.49	-0.39	-0.40	-0.45
Sit-ups	-0.40	-0.33	-0.35	-0.35	-0.35	-0.36	-0.35	-0.22	-0.30	-0.29	-0.37	n.s
Push-ups	-0.55	-0.49	-0.50	-0.46	-0.55	-0.60	-0.55	-0.39	-0.51	-0.53	-0.52	-0.36
DMR	-0.49	-0.32	-0.33	-0.56	-0.55	-0.35	-0.49	-0.56	-0.55	-0.38	-0.49	-0.55

CMJ = countermovement jump; SJL = standing long jump; Power$_{max}$ = maximal power of 6 second cycle ergometer; Power$_{ave}$ = average power of 6 second cycle ergometer; MVC$_{lower}$ = maximal voluntary contraction of the lower extremities; MVC$_{upper}$ = maximal voluntary contraction of the upper extremities; DMR = dead mass ratio; KB = kettlebell; Evac = evacuation; Total = total time of the run

The multiple linear regression analysis showed that CMJ, Power$_{ave}$, push-ups were significantly associated with the first run time of RSMT. Together these variables explained 58% ($R^2=0.58$, $p < 0.001$, F=48.64) of the variance in the RSMT time. For the second run time,3.2 loaded run, Power$_{ave}$, push-ups explained 60% ($R^2=0.60$, $p < 0.001$, F=52.19). The latter three variables (3.2 loaded run, Power$_{ave}$, push-ups) explained 51% ($R^2=0.51$, $p < 0.001$, F=36.96) of the variance the third run time.

Significant predictors of the crawling time in the first RSMT run included isometric lower body strength and push-up performance ($R^2=0.33$, $p < 0.001$, F=26.4). Crawling times of the second and third runs were predicted with Cooper test result, isometric lower body strength and push-up performance ($R^2=0.44$, $p < 0.001$, F=27.09) and DMR, isometric lower body strength and push-ups ($R^2=0.38$, $p < 0.001$, F=21.08), respectively.

The linear regression also showed that kettlebell carry time was explained by Power$_{ave}$ and push-ups ($R^2=0.44$, $p < 0.001$, F=41.63) in the first run, 3.2 km loaded run. Power$_{ave}$ and push-ups explained

(R^2=0.50, $p < 0.001$, F=35.01) in the second run, and, 3.2 km loaded run, $\text{Power}_{\text{ave}}$ and push-ups (R^2=0.44, $p < 0.001$, F=27.92) in the third run, respectively.

3.2 km loaded run, CMJ and $\text{Power}_{\text{ave}}$ explained 57% (R^2=0.57, $p < 0.001$, F=47.23) of the variance in casualty evacuation time in the first run. In the second run, 3.2 km loaded run, and $\text{Power}_{\text{ave}}$ together explained 55 % (R^2=0.55, $p < 0.001$, F=63.86), and for the third run, 3.2 km loaded run, $\text{Power}_{\text{ave}}$ and DMR explained 50 % (R^2=0.50, $p < 0.001$, F=34.85) of the variance in casualty evacuation time.

DISCUSSION

The main findings of the present study showed that lower body explosive force production, anaerobic endurance and upper body strength endurance together explained 58 % of the variance in the first RSMT ($p<0.001$). When RSMT was performed repeatedly the role of explosive force production was decreased and aerobic endurance increased. Additionally, the actual results of the investigation, do not necessarily support the importance of military specific endurance for repeat efforts. For example, the 3.2km loaded march had a declining correlation in the third RSMT trial (both individually and also within the multiple regression). Although the present study showed the increasing importance of occupational endurance capacity (e.g. performance time in 3.2 km loaded run) during repeated military specific test consisting of common occupational tasks such as sprints, crawling, load carriage and casualty evacuation, more research is needed to confirm its meaning during repeated task specific exercises.

The results confirmed findings from previous studies (Nindl et al. 2015, Kyröläinen et al. 2018, Vaara et al. 2021) reporting the role of strength and anaerobic capacity during high-intensity type of combat duties. To the best of the authors´ knowledge, this study is among the first ones to report changes in critical performance variables of repeated military occupational tasks during accumulating fatigue, and the associations between these changes and occupational tasks. The presented results are logical and relevant for optimization of combat readiness. Movement in the battlefield most likely includes several consecutive high-intensity bursts of activities that cannot be completely determined in advance. Thus, cumulative fatigue ultimately attenuates movement velocity of a soldier and thereby, increase the risk of injury or even death (Billing et al. 2015, Blount et al. 2013, Stein et al. 2022). Therefore, high levels of strength as well as anaerobic and aerobic endurance are essential physical qualities of a soldier with increasing role of endurance capacity in duties with repetitive nature.

The accumulation of fatigue, as observed in the present study by increases in blood lactate levels, had negative impact especially on tasks requiring activation of large muscle groups, such as crawling, load carriage and casualty evacuation. The average duration of RSMT increased by 19% and 34% from the first run to the second and third runs, respectively. The decrement in physiological readiness state of the body had also impact on prediction models. In the first run, which was performed in a recovered state, the combination of CMJ, mean anaerobic power and push-up performance explained 58 %. In the second (R^2 = 0.60) and third (R^2 = 0.51) run of the RSMT, CMJ was replaced with 3.2 km loaded run time in the regression model while mean anaerobic power and push-up performance remained in the model. These results clearly demonstrate that the role of explosive power of the lower extremities decreases and military specific aerobic endurance increases when occupational performance is assessed under acute fatigue even during a short high-intensity test. In general, these results are in line with a prior study utilizing a combination of military tasks performed in a recovered state (Pihlainen et al. 2018).

One interesting finding is that while only small differences in correlations between the 12-min run or the 3.2 km loaded run and the first run of RSMT were observed, the relationship with the 3.2 loaded run was stronger during the latter two runs. Also, only 3.2 km run entered the regression analyses but not the 12-min run. Lyons et al (2005) showed that load carriage performance with increasing loads (>20 kg) was associated more with absolute than relative oxygen uptake. This may hold true also with the 3.2 km loaded run when compared to the 12-min run performed in light sports clothing. It has been reported that fitness tests performed only with body mass may not resemble adequately military occupational performance. Indeed, body weight resistance-based test favor light individuals while most operative duties are performed carrying external loads (Vanderburgh et al. 2008). There are several studies supporting the theory that absolute maximal oxygen uptake is more important than relative maximal oxygen uptake in military tasks such as heavy load carriage and casualty evacuation, both of which require significant simultaneous contribution of the neuromuscular and the cardiovascular system (Vaara et al. 2021). However, since the correlation between the 3.2 km run time and RSMT was lower in the second compared to the third run, further studies are warranted with more than three runs to confirm the increasing contribution of military specific endurance performance (and also, absolute VO_2max) during repeated interval-type of occupational stress, such as the RSMT.

In the present study, crawling time increased by 18% between the first and second run and by 40% during the last run. Faster crawling performance has been associated with higher aerobic fitness, strength endurance of the upper body and maximal strength of the lower body in earlier studies (Hauschild et al. 2017). The results of this study are line with the above mentioned as crawling time of the first run was associated with maximal isometric strength of the lower body as well as push-up performance ($R^2 = 0.33$). Regression model of the second run included the same variables as the first one and the 12-min running test result ($R^2 = 0.44$), thus reinforcing previous findings. Crawling time of the third run was associated with DMR, maximal isometric strength of the lower body and 1-min push-up performance, explaining 44 % of the crawling performance. The associations are logical in a sense that crawling is performed with all four extremities contributing to the performance time.

Previous studies have confirmed the importance of absolute aerobic capacity and lower body strength as well as strength endurance in load carriage performance (Rayson et al. 2000). Load carriage is one of the most common and studied form of military occupational activity (Knapik et al. 2004). Load carriage may refer to walking with combat load but in this paper, also manual material handling tasks involving carrying external loads by hands are included in this category. Examples of such military tasks are stretcher carry, and transporting sandbags, food supplies or ammunition boxes. Duration, load, intensity and therefore, energy and force production demands vary significantly in such tasks depending on operative situation. As the present study showed, even a short, standardized load carriage performance weakens by 15% already after 37 seconds (average) of high-intensity physical activity, followed by 1 min of recovery. Furthermore, the regression analyses showed that whereas mean anaerobic power (W) and push-up performance were the main predictors (R^2 = 0.44) of the load carriage performance in the first run, prediction model for the second (R^2 = 0.50) and third run (R^2 = 0.44) was improved by addition of 3.2 km loaded run time. Thus, the role of aerobic endurance capacity increased when load carriage task was performed under accumulating fatigue.

Casualty evacuation may not be among the most common military tasks but obviously a critical and physically demanding one (Larsson et al. 2020). Angeltveit et al. (2016) reported that the highest correlations between physical fitness, body composition variables, and performance time of an 80-kg casualty drag with an average performance time of 50 s were observed in body mass (r = -0.82), lean body mass (r = -0.72), absolute aerobic capacity (r = -0.72), anaerobic capacity (r = -0.68) and 1-RM leg press (r = -0.42). Regression model showed that 72% of the variance in casualty drag performance was explained by body mass and absolute aerobic capacity (Angeltveit et al. 2016). In the present study, 57% of the variance of casualty evacuation time in the first round´s performance could be explained by 3.2 km loaded run time, CMJ and mean anaerobic power. During the second round, CMJ was excluded from the prediction model (R^2 = 0.55). Finally, the prediction model of the third round consisted of 3.2 km loaded run time, mean anaerobic power and DMR, explaining 50% of the variance in casualty evacuation performance. Thus, military specific aerobic endurance and anaerobic performance are essential fitness determinants of casualty drag. However, while explosive force production is important physical attribute for effective casualty evacuation in a recovered state, high relative muscle mass is more important under increased fatigue.

Regarding previous military task simulation studies, a large number (n = 114) of participants as well as novel application of using several test runs with standardized recovery periods can be considered as strengths of the study. However, in combat the recovery periods cannot be predetermined, in the present study 1 – minute recovery was decided based on subject matter experts. The loading protocol was standardized by using the regular individual combat gear but the test was performed without assault rifle for security reasons. The weight of the weapon is approximately 3.5 kg. In addition, soldiers typically carry other unit equipment during operative activity, which increases DMR, physical stress and weakens mobility (O´Neal et al. 2014). Changes in carried load may have had an impact on regression variables, which is a limitation of the study and need to be taken into consideration when interpreting the results.

When designing training programs for soldiers, previous studies have shown that load carriage (Santtila et al. 2010), manual material handling (Drain et al. 2016), and casualty evacuation (Ojanen et al. 2020) can be improved during military service. It seems that, because of high overall aerobic training load during military training, increased intensity and decreased total volume of physical training along with emphasis on strength training may enhance occupational performance during military service, (Burley et al. 2020, Vaara et al. 2021).

CONCLUSION

In conclusion, the findings of this study are in line with previous research highlighting the importance of lower body maximal strength, anaerobic power and upper body strength endurance in several military tasks performed in a recovered state. However, when tasks are performed in a repeated, fatiguing manner, the role of military specific aerobic endurance increases. These results underline that both strength and endurance training must be applied in order to develop soldier's occupational physical performance.

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