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Physical Fitness Determinants of a Military Casualty Evacuation Test

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ABSTRACT
Introduction:
Casualty evacuation has been identified as a typical and essential single military task which every soldier should be able to perform rapidly during combat. Previous studies suggest that casualty evacuation is typically conducted by dragging and demands e.g., lean body mass and anaerobic performance. Association of physical fitness with casualty evacuation by dragging has been studied widely but previous studies lack comprehensive assessment of all physical fitness determinants. The purpose of the present study was to examine comprehensively how casualty emergency evacuation (CEE) performance associates with physical fitness and body composition.

Materials and Methods:
A total of 25 conscripts (20 men, 5 women) volunteered for measurements of height, weight, waist circumference, body composition, 1-min sit-ups and push-ups, grip strength, isometric bench and leg press, standing long jump, 30-s cycle ergometer test, and 12-min run test. Subjects performed a CEE test in which evacuation time (ET), heart rate, blood lactate concentration, and rate of perceived exertion were measured. In the CEE test, subjects wore combat gear (11.7 ± 1.6 kg) and dragged a doll wearing combat gear (80.2 kg) 28 m while crawling (go round two cones, Z-pattern) and 20 m upright (straightforward). Correlations and backward regression analysis were used for statistical analyses. The level of significance was set to $P \leq .05$.

Results:
Evacuation time lasted on average 87 ± 32 s with a peak heart rate of 184 ± 6 bpm, lactate concentration of 9.4 ± 2.7 mmol/l, and RPE of 17 ± 1. Evacuation time correlated inversely and strongly with anaerobic capacity and power ($r = -0.72$-0.78, $P \leq .001$), but not with aerobic fitness. Inverse and strong correlations were observed between ET and maximal strength variables ($r = -0.58$-0.69, $P \leq .01$), whereas muscular endurance and ET revealed non-significant correlations. Evacuation time correlated moderate to strongly with body fat percentage ($r = 0.48$, $P \leq .05$) and inversely with lean body mass ($r = -0.74$, $P \leq .001$) and body height ($r = -0.53$, $P \leq .01$). The backward regression analysis showed that anaerobic capacity (standardized $\beta = -0.52$, $P \leq .001$), fat percentage (standardized $\beta = 0.40$, $P \leq .001$), and isometric leg press (standardized $\beta = -0.25$, $P \leq .1$) together explained the variance of ET significantly (adjusted $R^2 = 0.84$, $P \leq .001$).

Conclusions:
This study examined thoroughly how different physical fitness dimensions and body composition relate to a CEE test performed by a combination of dragging while crawling and in upright position. Casualty emergency evacuation was discovered as a high-intensity military task, which demands most importantly high anaerobic performance, lean body mass, and maximal strength capabilities. Improving these dimensions of physical fitness should be considered highly important as CEE is essential and possibly one of the most demanding military tasks which every soldier should be able to conduct in combat. From operational perspective, it is relevant that soldiers are able to perform CEE during operations; therefore, further research is needed on how acute operational stress changes the nature of CEE and its physical determinants.

INTRODUCTION

Soldiers face multiple different stressors during operations, such as load carriage and environmental circumstances. Operational tasks typically cause energy deficiency and psychological stress combined with sleep deprivation. These stressors lead to a decrease in soldiers' physical capability to perform

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their duties.[1] In military operations, soldiers perform physically demanding tasks in nearly 80% of their daily duties.[2] A panel of specialists concerning soldiers' physical performance has scored the importance of different physical characteristics in various military tasks. According to the panel, the most important physical features were strength and power in single military tasks.[3] A meta-analysis suggests that soldiers' capability to perform their duties is highly related to physical fitness tests measuring cardiorespiratory endurance, lower body strength, and upper body endurance.[4]

A technical research group concerning operational physical fitness optimization has identified 3 typical military tasks: marching, digging, and manual materials handling (lifting, lifting and carrying, casualty carrying, etc.).[5] A recent review has also identified 3 essential military tasks which are load carriage, manual material handling, and casualty evacuation.[6] Different military tasks have been identified in order to determine suitable task-related fitness tests for soldiers. For example, U.S. Army has used loaded march, sandbag carry, casualty drag, casualty evacuation, and movement under fire.[7] Casualty drag has been identified to be a very important task, which soldiers should be able to perform in less than 5 min.[8] Casualty evacuation is possibly one of the most demanding single military tasks (typically conducted by dragging),[9] and every soldier should be able to perform it.

Previous studies consider the physical demands of various casualty evacuation performance. Typically, subjects have dragged a simulated casualty, which has weighed 54-82 kg, in an upright position.[10–12] Casualty drag distances have varied from 15 to 56 m.[10,13,14] Results from the previous studies suggest that body mass,[13,15] lean body mass,[11,13,16] aerobic endurance,[13] and anaerobic performance[10,13–15] are positively related to casualty drag performance. Also, positive associations have been found with upper body muscular endurance and strength,[14] lower body strength and power,[13] and grip strength.[12,14,16] All of the relations presented in these studies have been moderate to strong.

Previous studies and their results are challenging to compare because there is a large variety in subjects, equipment worn by subjects, casualty drag test used and fitness tests performed. Most of these studies have not performed measurements including all physical fitness dimensions, such as aerobic endurance, anaerobic performance, muscular endurance and whole-body strength capabilities, and have not necessarily included body composition. The purpose of this study was to investigate how a casualty evacuation test—which simulates casualty emergency evacuation (CEE) from enemy fire to shelter—relates to body composition and physical fitness.

METHODS

Experimental Approach to the Problem

Voluntary conscripts from medical non-commissioned officer course participated in the study because their training consisted of activities related to CEE, thus ensuring that they were familiar with CEE performance. This minimized the learning effect for CEE in this study. All measurements were conducted after subjects had learned casualty evacuation techniques during their military training. Subjects had participated in 8-week basic training and a 7-week general non-commissioned officer course before participating in the study.

Body composition and physical fitness were measured thoroughly to achieve a broad perspective of the subjects' physical condition. Physical fitness tests included standing long jump, 1-min sit-ups, 1-min push-ups, and 12-min run, which are used for fitness testing in Finnish Defence Forces. These tests were familiar for the subjects, and thus, negligible learning effect may have occurred. Also, additional tests were used to measure subjects' physical fitness comprehensively. These tests were selected to measure maximal strength capabilities and anaerobic performance, which have been identified as important in casualty evacuation, according to previous research.[10,12–16] Additional tests included isometric force measurements of the lower and upper body extremities, grip strength, and anaerobic test.

The study was performed in accordance with the Declaration of Helsinki and approved by the Research Board of National Defence University and the Ethics Committee of Helsinki and Uusimaa Medical District. Finnish Defence Command had approved the study implementation (AO6179).

Subjects

Measurements were conducted during a medical non-commissioned officer course in the Armored Brigade, Army, Finnish Defence Forces. In total, 25 conscripts (20 men, 5 women) participated voluntarily in the study and signed an informed consent. Subjects' mean age was 20 ± 2 years. Subjects, including mixed gender, represent a very common group of soldiers in Finnish Defence Forces. Therefore, subjects were analyzed as 1 group. In addition, only 5 women were present in this study, which did not allow for separate analysis of men and women.

Procedures

Casualty emergency evacuation is performed under enemy fire immediately after a soldier is wounded in action. The purpose of CEE is to evacuate casualty to a cover from enemy fire, in order to start tactical casualty combat care. Before the tests, subject-matter instructors ($n = 74$) were asked via a questionnaire to describe a typical CEE task including techniques used. The results showed that first, the casualty is dragged while crawling, then the CEE is continued upright because of the demands of the operational environment. Based on these findings, a new CEE test was developed. The CEE test protocol is presented in Figure 1.

The test was conducted indoors. Casualty was simulated with a mannequin wearing light combat gear (uniform, vest, helmet). Casualty's total mass was 80.2 kg, which was nearly equal to subjects' average mass with light combat gear.

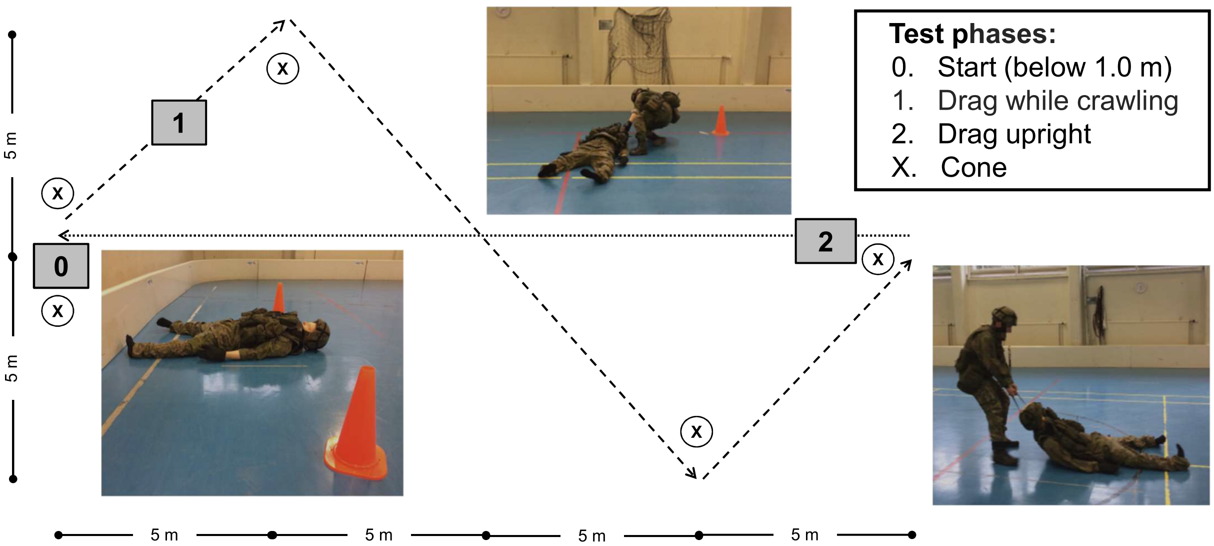

Figure 1. Casualty emergency evacuation test procedure.

Subjects wore similar gear as the mannequin (11.7 ± 1.6 kg). The CEE test started with a subject grabbing from the casualty's vest in a crawling position (whole body below 1.0 m). The test started from a mark. In the first phase, the subject dragged the casualty a Z-pattern while crawling (28 m). After the first phase, the subject stood up and continued dragging upright (20 m). The test ended when the casualty reached the starting line. Evacuation time (ET) was measured in seconds. Subjects were encouraged to perform one's best during the test.

Determinants of CEE Performance

Measurements were executed alongside subjects' military training. On day 1, anthropometric and bioimpedance measurements were conducted first thing in the morning after an overnight fast. On the same day, strength tests were conducted in the following order: standing long jump, grip strength, isometric bench and leg press, 1-min sit-ups and 1-min push-ups. On day 3, the CEE test was performed in the morning and anaerobic performance was tested in the afternoon. At least 3 h of active and passive recovery was required between the tests. In all, 12-min run test was executed 6 weeks later because of military field trainings. Subjects did not perform progressive fitness training during those 6 weeks.

Body composition was assessed via anthropometric and bioimpedance measurements. Height and waist circumference were measured with a commercial scale. Bioimpedance analysis was conducted after at least 8 h of fasting in the morning (InBody 720, Biospace, Soul, South Korea). Variables determined from bioimpedance analysis were body mass, body mass index, lean body mass, fat mass, and fat percentage.

Lower body power was assessed with standing long jump.[17] This test has been found reliable (intra-class correlation, ICC = 0.80). All subjects had done the test previously, which may increase its reliability.[18] The test was conducted 3 times, with at least 2 min of rest in between each test, with a measurement accuracy of 1 cm.

Grip strength was measured seated with an elbow angle of 90 degrees.[19] A dynamometer was used (Saehan Corporation, Masan, South Korea). The test is highly reliable ($r = 0.81$).[20] Both hands were tested 3 times with at least 2 min of rest between each test. The accepted test score was the mean of each hand's best result in kilograms.

Isometric bench press was used to assess maximal strength of the upper extremities. A dynamometer was used (Leg and bench press dynamometer, Jyväskylä University, Jyväskylä, Finland). Isometric measurements with an elbow angle of 90 degrees have been found valid ($r = 0.78$) and highly reliable (ICC = 0.82-0.92).[21] Test was done 3 times with a rest of 30 s. Test score was the best trial in kilograms.

Isometric leg press was used to assess maximal strength of the lower extremities. A dynamometer was used (Leg and bench press dynamometer, Jyväskylä University, Jyväskylä, Finland). Isometric measurements have been found valid ($r = 0.77$-0.97) and highly reliable (ICC = 0.97-1.00).[22,23] The test was done 3 times with 30 s of rest between each test, with a knee angle of 107 degrees. The accepted test score was the best trial in kilograms.

Muscular endurance was assessed with 1-min sit-up[24] and 1-min push-up[25] tests. The sit-up test has been found highly reliable (ICC = 0.92), as well as the push-up test (ICC = 0.95).[26] The test score used for analysis was repetitions per minute.

Anaerobic performance was assessed with a 30-s sprint test using a cycle ergometer (Wattbike Trainer, Wattbike, Nottingham, United Kingdom). Ergometers have been found highly accurate, with a measurement error of less than 2%.[27] Average power was used to assess anaerobic capacity (AC) and maximal power for maximal anaerobic power (MAP). Using the manufacturer's test protocol, AC and MAP have been found highly reliable among cyclists (ICC = 0.97-0.99).[28]

Aerobic fitness was measured with a 12-min run test. The test was conducted on an outdoor track. The 12-min run test has been found highly valid in assessing maximal oxygen uptake ($r = 0.90$).[29]

Casualty emergency evacuation was tested as presented above. A familiarization session was done before the test. The test protocol was introduced and subjects dragged the mannequin by trying both techniques (crawl, upright) before the test. A comparable casualty evacuation test used in previous study has been found moderately reliable (ICC = 0.78) after first trial and highly reliable (ICC = 0.89) after second trial.[13] Heart rate (HR) was measured using a monitor (Bodyguard 2, Firstbeat Technologies, Jyväskylä, Finland). Lactate concentration (LC) was measured from a fingertip immediately before and 5 min post-test (Biosen S-line Lab+, EKF Diagnostic, Cardiff, Iso-Britannia). Subjects assessed their rate of physical exertion (RPE) on a scale of 6-20[30] at pre-test, immediately post-test, and 5 min post-test.

Statistical Analyses

Collected data was analyzed with IBM SPSS Statistics. Results are presented as mean, SD, and range of variation. Alpha level of significance was $P \leq .05$.

Normality was tested with Shapiro-Wilk test. Histograms and scatterplots were examined from variables with a level of significance $P \leq .05$. The majority of the variables were found to be normally distributed, but skewness was detected concerning ET. Therefore, non-parametric tests were conducted. Correlations were determined with Spearman's correlation coefficient. Backward regression analysis was used to form a model which could explain performance in the CEE test.

RESULTS

Subjects' body composition and physical fitness are presented in **Table 1**. Evacuation time lasted on average 87 ± 32 (50-171) s and subjects' peak HR during the CEE test was 184 ± 6 (169-192) bpm. Lactate concentration pre-CEE was 1.4 ± 0.5 (0.7-2.7) mmol/l, and 5 min post-CEE was 9.4 ± 2.7 (2.8-14.5) mmol/l. Rate of physical exertion was pre-CEE 11 ± 2 (7-13), post-CEE 17 ± 1 (14-19), and 5 min post-CEE 14 ± 2 (10-18).

Correlations of ET with body composition and physical fitness are presented in **Table 2**. Evacuation time correlated inversely and strongly with AC, MAP, lean body mass, isometric bench, and leg press ($r = -0.69$-0.78, $P \leq .001$). Evacuation time had moderate inverse correlations with isometric grip strength, standing long jump, and body height ($r = -0.53$-0.58, $P \leq .01$). Also, fat percentage was moderately correlated with ET ($r = 0.48$, $P \leq .05$). The strongest correlations are presented in Figure 2.

The backward regression analysis showed that AC (standardized $\beta = -0.52$, $P \leq .001$), fat percentage (standardized $\beta = 0.40$, $P \leq .001$) and isometric leg press (standardized $\beta = -0.25$, $P \leq .1$) altogether explained the variance in ET significantly by 84% (adjusted $R^2 = 0.84$, $P \leq .001$).

Table 1. Body Composition and Physical Fitness Results

Variable	Mean ± SD	Range of variation
Body height (cm)	178.0 ± 9.5	160.5–196.5
Body mass (kg)	71.1 ± 10.9	54.2–102.6
Body mass index (kg/m^2)	22.7 ± 3.1	18.8–29.1
Lean body mass (kg)	33.9 ± 5.5	23.3–47.4
Fat mass (kg)	11.3 ± 6.3	3.0–29.1
Fat percentage (%)	15.7 ± 7.8	4.7–35.0
Waist circumference (cm)	78.5 ± 6.5	68.5–96.0
1-min sit-ups (reps/min)	43 ± 7	30–58
1-min push-ups (reps/min)	33 ± 13	13–66
Grip strength (kg)	45.5 ± 7.0	32.5–62.0
Isometric bench press (kg)	86 ± 16	62–118
Isometric leg press (kg)	329 ± 98	171–547
Standing long jump (m)	2.11 ± 0.26	1.65–2.48
AC (W)	573 ± 71	379–663
MAP (W)	839 ± 147	547–1140
12-min run test (m)	2610 ± 230	2150–2960

Table 2. Body Composition and Physical Fitness Correlations with ET

Variable	Spearman's *r*
AC	−0.78 ***
Lean body mass	−0.74 ***
MAP	−0.72 ***
Isometric bench press	−0.69 ***
Isometric leg press	−0.69 ***
Grip strength	−0.58 **
Standing long jump	−0.57 **
Body height	−0.53 **
Fat percentage	0.48 *
12-min run test	−0.40
1-min push-ups	−0.39
Fat mass	0.36
Body mass	−0.30
Waist circumference	−0.19
1-min sit-ups	0.05
Body mass index	−0.02

*$P \leq .05$,
**$P \leq .01$,
***$P \leq .001$.

DISCUSSION

The main findings of the present study revealed that casualty evacuation test, which simulates CEE to cover from enemy fire in operational environment, was strongly associated with anaerobic performance, lean body mass, and

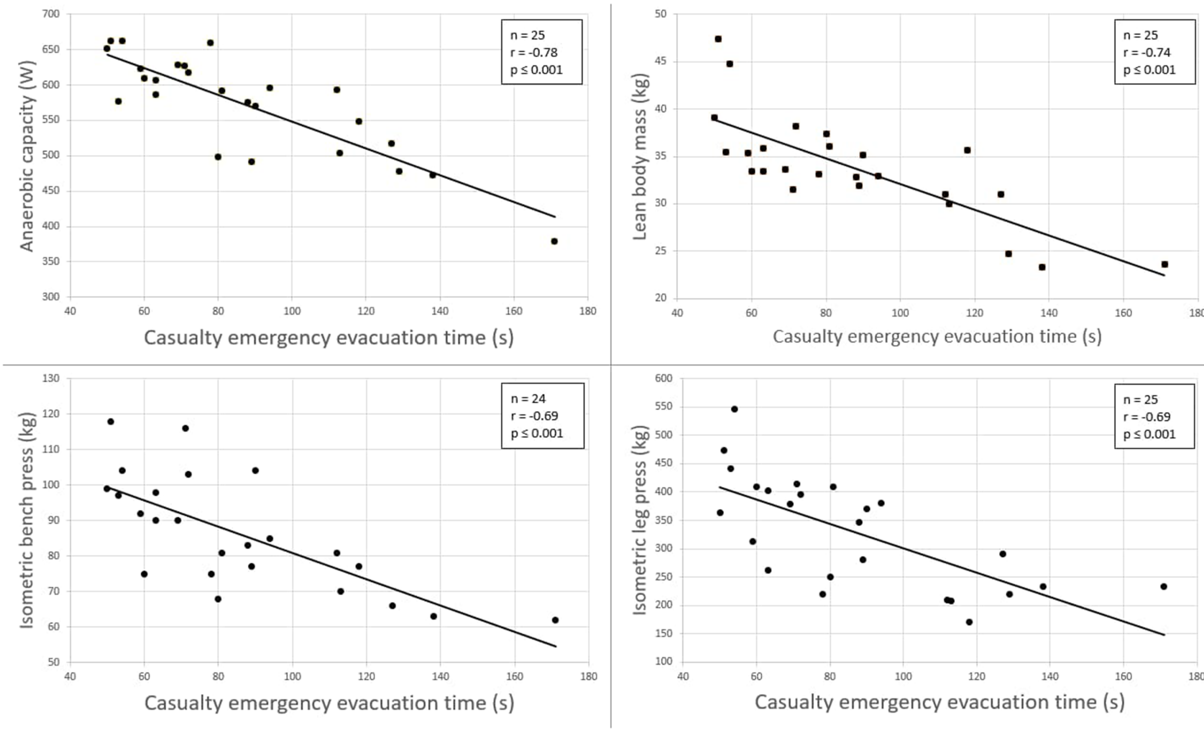

Figure 2. Spearman's correlation coefficient of ET with AC, lean body mass, isometric bench press, and isometric leg press.

maximal strength capabilities of the lower and upper extremities. Aerobic endurance and muscular endurance did not significantly predict CEE.

The duration of the CEE test was relatively short. Heart rate elevated to a near-maximal level, and LC increased significantly 5 min post-test. These observations, combined with strong and inverse correlation between anaerobic performance and ET support the conclusion that CEE is a highly anaerobic task. This is a result of two factors concerning the nature of CEE. First, CEE to cover from enemy fire is a task which must be performed as quickly as possible. Second, casualty makes up a heavy external load, which can easily overrun soldier's own body mass. In the real operational environment the load will be even higher, in addition to challenging terrain, body armor, and carriage of ammunition. The importance of anaerobic performance is seen with the present study findings, and is supported by previous studies.[10,13–15]

High lean body mass and maximal strength capabilities were also significantly associated with performance in CEE. Because of the external load of casualty, it is logical that lean body mass and muscle strength are important factors for CEE performance, as high absolute strength levels are related to lean body mass. It is especially crucial that soldiers are able to initiate evacuation of the casualty. If the soldier does not have sufficient strength capabilities to move the casualty, they would not be able to perform the task. In previous studies, body mass[13,15] and lean body mass[11,13,16] have also been considered relevant explanatory factors for a successful CEE, consistent with the results of the present study.

Previous studies have made controversial findings concerning maximal strength and muscular endurance. Therefore, the importance of maximal strength features and muscular endurance is not explicit. Some studies have found significant correlations between casualty evacuation and upper body muscular endurance and strength,[14] lower body strength,[13] and grip strength.[12,14,16] These discrepancies between results can be partially explained by the selection of physical fitness determinants in previous studies. Most of the previous studies have neither studied nor reported correlations between casualty evacuation and the whole spectrum of body composition and physical fitness.

Casualty evacuation is one of the most physically demanding single military tasks, which every soldier should be able to perform. This study confirms previous results that lean body mass and anaerobic performance are crucial in CEE.[13] Results also emphasize the importance of maximal strength. Aerobic performance and muscular endurance seem to be much less important compared to lean body mass, maximal strength and anaerobic performance. This study, along with previous studies, have tested subjects without operational stress before CEE. Therefore, it may be advantageous to study how CEE performance and its determinants may change after operational stress induced acute fatigue. From an operative perspective, it may be more relevant to study CEE in the fatigued state in soldiers, which they face during operations, rather than in a recovered condition, which was used in the present and previous studies.[15]

The present study used a different kind of test to simulate CEE compared to previous studies.[13–16] In the previous studies, the evacuation test was exclusively composed of dragging the casualty only in upright position. The combination of techniques, including dragging by crawling and in upright position, better simulates the real task during operations, at least in Finnish operational environment. Also, the nature of CEE transforms during the first 28 m, where the casualty is being dragged by crawling and then 20 m in the upright position. The biomechanics during the task changes significantly and raises the duration of CEE. These features might have affected the results in the present study.

The CEE test in this study was more complex concerning the technique used, when compared to previous studies. This might have decreased the reliability of the test used and, therefore, decrease the validity of study results. However, the CEE test used in this study was not designed to be a highly realiable work-related fitness test. It was developed to simulate the task in an operational environment. Further research is needed before the CEE test could be used to test soldiers' working ability. Also, the 12-min run test was performed 6 weeks after the other tests were conducted because of practical reasons. Because the subjects did not perform progressive fitness training during their course, but participated in 4 military field trainings, the effect on result validity can be assessed as tolerable.

Military operations challenge soldiers' physical capability in many ways. Soldiers face multiple stressors, which vary from environmental stress and sleep deprivation, to intense physical activies in combat combined with energy deficiency.[1] Previous studies have identified that operational stress causes a significant decrease in soldiers' body mass,[31–34] lower body anaerobic performance[32,34] and maximal strength capabilities concerning upper[31] and lower extremities.[31,33] This phenomenon challenges soldiers' ability to perform their duties in combat. As physical capability decreases during operations, the nature of many physically demanding tasks may change compared to a recovered state. Additionally, it is crucial for soldiers to have a sufficient reserve in physical performance and the ability to recover during military operations.

An important approach for future research about casualty evacuation could be to study which physical fitness components are crucial for maintaining sufficient physical capability for CEE, despite the accumulation of operational stress. In addition, it could be relevant to understand how more detailed physiological systems such as autonomous nervous system, hormonal, and inflammatory markers are linked to CEE during accumulated operational stress. As casualty evacuation is one of the most demanding military tasks, which every soldier should be able to conduct, this information is valuable for assessing the optimal balance of physical features for soldiers.

CONCLUSIONS

Casualty emergency evacuation to cover from enemy fire in the operational environment is a highly anaerobic task, which demands anaerobic performance, lean body mass, and maximal strength capabilities. Casualty emergency evacuation is possibly one of the most demanding military actions, which every soldier should be able to conduct. Therefore, physical training developing these dimensions of physical fitness is highly important. Nevertheless, it is partly unknown how acute operational stress changes the nature of CEE and its physical determinants and that warrants future studies.

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CLINICAL TRIAL REGISTRATION

Not applicable.

INSTITUTIONAL REVIEW BOARD (HUMAN SUBJECTS)

The study was performed in accordance with the Declaration of Helsinki and approved by the Research Board of National Defence University and the Ethics Committee of Helsinki and Uusimaa Medical District. Finnish Defence Command had approved the study implementation (AO6179).

INSTITUTIONAL ANIMAL CARE AND USE COMMITTEE (IACUC)

Not applicable.

INDIVIDUAL AUTHOR CONTRIBUTION STATEMENT

J.M., H.K., and J.P.V. designed the study; J.M. collected and analyzed the study data; J.M., H.K., and J.P.V. interpreted the study findings; J.M. wrote the manuscript; H.K. and J.P.V. edited the manuscript.

INSTITUTIONAL CLEARANCE

Instutional clearance does not apply.

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CONFLICT OF INTEREST STATEMENT

None declared.

DATA AVAILABILITY

The data underlying this article is owned by Finnish Defence Forces. Data can be shared upon request to the corresponding author only with permission of Finnish Defence Command.

REFERENCES

1. Henning PC, Park B-S, Kim J-S. Physiological decrements during sustained military operational stress. *Mil Med*. 2011;176(9):991–7. 10.7205/milmed-d-11-00053
2. Boye MW, Cohen BS, Sharp MA, et al. U.S. Army physical demands study: prevalence and frequency of performing physically demanding tasks in deployed and non-deployed settings. *J Sci Med Sport*. 2017;20(4):S57–S61. 10.1016/j.jsams.2017.08.014
3. Nindl BC, Alvar BA, Dudley JR, et al. Executive summary from the National Strength and Conditioning Association's second Blue Ribbon Panel on military physical readiness: military physical performance testing. *J Strength Conditioning Res*. 2015;29(11S):S216–20. 10.1519/JSC.0000000000001037

4. Hauschild VD, DeGroot DW, Hall SM, et al. Fitness tests and occupational tasks of military interest: a systematic review of correlations. *Occup Environ Med*. 2017;74(2):144–53. 10.1136/oemed-2016-103684
5. Jaenen S. Identification of Common Military Tasks. North Atlantic Treaty Organisation—Research and Technology Organisation. Optimizing operational physical fitness—Final Report of Task Group 019. AC/323(HFM-080)TP/200 2009: 2-1-2-6.
6. Vaara JP, Groeller H, Drain J, et al. Physical training considerations for optimizing performance in essential military tasks. *Eur J Sport Sci*. 2022;20(1):43–57. 10.1080/17461391.2021.1930193
7. Foulis SA, Sharp MA, Redmond JE, et al. U.S. Army physical demands study: development of the occupational physical assessment test for combat arms soldiers. *J Sci Med Sport*. 2017;20(4):S74–8. 10.1016/j.jsams.2017.07.018
8. Sharp MA, Cohen BS, Boye MW, et al. U.S. Army physical demands study: identification and validation of the physically demanding tasks of combat arms occupations. *J Sci Med Sport*. 2017;20(4):S62–7. 10.1016/j.jsams.2017.09.013
9. Reilly T. Canada's physical fitness standard for the land force: a global comparison. *The Can Army J*. 2010;13(2):59–69.
10. Arvey RD, Landon TE, Nutting SM, et al. Development of physical ability tests for police officers: a construct validation approach. *J Appl Psychol*. 1992;77(6):996–1009. 10.1037/0021-9010.77.6.996
11. Hendrickson NR, Sharp MA, Alemany JA, et al. Combined resistance and endurance training improves physical capacity and performance on tactical occupational tasks. *Eur J Appl Physiol*. 2010;109(6):1197–208. 10.1007/s00421-010-1462-2
12. Michaelides MA, Parpa KM, Henry LJ, et al. Assessment of physical fitness aspects and their relationship to firefighters' job abilities. *J Strength Conditioning Res*. 2011;25(4):956–65. 10.1519/JSC.0b013e3181cc23ea
13. Angeltveit A, Paulsen G, Solberg PA, et al. Validity, reliability, and performance determinants of a new job-specific anaerobic work capacity test for the Norwegian Navy Special Operations Command. *J Strength Conditioning Res*. 2016;30(2):487–96. 10.1519/JSC.0000000000001041
14. Rhea MR, Alvar BA, Gray R. Physical fitness and job performance of firefighters. *J Strength Conditioning Res*. 2004;18(2):348–52. 10.1519/R-12812.1
15. Harman EA, Gutekunst DJ, Frykman PN, et al. Prediction of simulated battlefield physical performance from field-expedient tests. *Mil Med*. 2008;173(1):36–41. 10.7205/milmed.173.1.36
16. Williford HN, Duey WJ, Olson MS, et al. Relationship between fire fighting suppression tasks and physical fitness. *Ergonomics*. 1999;42(9):1179–86. 10.1080/001401399185063
17. Hickox LJ, Ashby BM, Alderink GJ. Exploration of the validity of the two-dimensional sagittal plane assumption in modeling the standing long jump. *J Biomech*. 2016;49(7):1085–93. 10.1016/j.jbiomech.2016.02.037
18. Hébert-Losier K, Beaven CM. The MARS for squat, countermovement, and standing long jump performance analyses: are measures reproducible?. *J Strength Conditioning Res*. 2014;28(7):1849–57. 10.1519/JSC.0000000000000343
19. Su CY, Lin JH, Chien TH, et al. Grip strength in different positions of elbow and shoulder. *Arch Phys Med Rehabil*. 1994;75(7):812–5. 10.1016/0003-9993(94)90142-2
20. Hamilton GF, McDonald C, Chenier TC. Measurement of grip strength: validity and reliability of the sphygmomanometer and Jamar grip dynamometer. *J Orthop Sports Phys Ther*. 1992;16(5):215–9. 10.2519/jospt.1992.16.5.215
21. Murphy AJ, Wilson GJ, Pryor JF, et al. Isometric assessment of muscular function: the effect of joint angle. *J Appl Biomech*. 1995;11(2):205–15. 10.1123/JAB.11.2.205
22. Blazevich AJ, Gill N, Newton RU. Reliability and validity of two isometric squat tests. *J Strength Conditioning Res*. 2002;16(2):298–304. 10.1519/1533-4287(2002)016<0298:RAVOTI>2.0.CO;2
23. McGuigan MR, Newton MJ, Winchester JB, et al. Relationship between isometric and dynamic strength in recreationally trained men. *J Strength Conditioning Res*. 2010;24(9):2570–3. 10.1519/JSC.0b013e3181ecd381
24. Parfrey KC, Docherty D, Workman RC, et al. The effects of different sit-and curl-up positions on activation of abdominal and hip flexor musculature. *Appl Physiol Nutr Metab*. 2008;33(5):888–95. 10.1139/H08-061
25. Fogelholm M, Malmberg J, Suni J, et al. Waist circumference and BMI are independently associated with the variation of cardio-respiratory and neuromuscular fitness in young adult men. *Int J Obesity*. 2006;30(6):962–9. 10.1038/sj.ijo.0803243
26. Augustsson SR, Bersås E, Thomas EM, et al. Gender differences and reliability of selected physical performance tests in young women and men. *Adv Physiother*. 2009;11(2):64–70. 10.1080/14038190801999679
27. Wainwright B, Cooke CB, O'Hara JP. The validity and reliability of a sample of 10 Wattbike cycle ergometers. *J Sports Sci*. 2017;35(14):1451–8. 10.1080/02640414.2016.1215495
28. Driller MW, Argus CK, Shing CM. The reliability of a 30-s sprint test on the Wattbike cycle ergometer. *Int J Sports Physiol Perform*. 2013;8(4):379–83. 10.1123/ijspp.8.4.379
29. Cooper KH. A means of assessing maximal oxygen intake—correlation between field and treadmill testing. *J Am Med Assoc*. 1968;203(3):135–8. 10.1001/JAMA.1968.03140030033008
30. Borg G. Perceived exertion as an indicator of somatic stress. *Scand J Rehabil Med*. 1970;2(2):92–8. 10.2340/1650197719702239298
31. Hamarsland H, Paulsen G, Solberg PA, et al. Depressed physical performance outlasts hormonal disturbances after military training. *Med Sci Sports Exercise*. 2018;50(10):2076–84. 10.1249/MSS.0000000000001681
32. Nindl BC, Leone CD, Tharion WJ, et al. Physical performance responses during 72 h of military operational stress. *Med Sci Sports Exercise*. 2002;34(11):1814–22. 10.1097/00005768-200211000-00019
33. Vaara JP, Kalliomaa R, Hynninen P, et al. Physical fitness and hormonal profile during an 11-week paratroop training period. *J Strength Conditioning Res*. 2015;29(11S):S163–S167. 10.1519/JSC.0000000000001033
34. Welsh TT, Alemany JA, Montain SJ, et al. Effects of intensified military field training on jumping performance. *Int J Sports Sci Med*. 2008;29(1):45–52. 10.1055/s-2007-964970

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