Journal of Strength and Conditioning Research™

OPEN

Effects of Combined Strength and Endurance Training on Body Composition, Physical Fitness, and Serum Hormones During a 6-Month Crisis Management Operation

Kai Pihlainen,[1] Heikki Kyröläinen,[2,3] Matti Santtila,[3] Tommi Ojanen,[4] Jani Raitanen,[5,6] and Keijo Häkkinen[2]

[1]Training Division, Helsinki, Defence Command, Finland; [2]Neuromuscular Research Center, Faculty of Sport and Health Sciences, University of Jyväskylä, Jyväskylä, Finland; [3]Department of Military Pedagogy and Leadership, National Defence University, Finnish Defence Forces, Helsinki, Finland; [4]Finnish Defence Research Agency, Finnish Defence Forces, Tuusula, Tuusula, Finland; [5]Faculty of Social Sciences (Health Sciences), Tampere University, Tampere, Finland; and [6]UKK Institute for Health Promotion Research, Tampere, Finland

Abstract

Pihlainen, K, Kyröläinen, H, Santtila, M, Ojanen, T, Raitanen, J, and Häkkinen, K. Effects of combined strength and endurance training on body composition, physical fitness, and serum hormones during a 6-month crisis management operation. *J Strength Cond Res* XX(X): 000–000, 2020—Very few studies have examined the impact of training interventions on soldier readiness during an international military operation. Therefore, the present study investigated the effects of combined strength and endurance training on body composition, physical performance, and hormonal status during a 6-month international military deployment consisting of typical peacekeeping tasks, e.g., patrolling, observation, and on-base duties. Soldiers ($n = 78$) were randomly allocated to a control group (C) or one of 3 combined whole-body strength and endurance training groups with varying strength-to-endurance training emphasis (Es = 25/75%, *SE* = 50/50% or Se = 75/25% of strength/endurance training). Body composition, physical performance (3000-m run, standing long jump [SLJ], isometric maximal voluntary contraction of the lower [MVC lower] and upper extremities [MVC upper], muscle endurance tests), and selected serum hormone concentrations were determined prior to training (PRE), and after 9 (MID) and 19 (POST) weeks of training. Within- and between-group changes were analyzed using linear regression models. The average combined strength and endurance training frequency of the total subject group was 3 ± 2 training sessions per week. No changes were observed in physical performance variables in the intervention groups, whereas SLJ decreased by 1.9% in C ($p < 0.05$). Maximal voluntary contraction lower increased by 12.8% in the combined intervention group ($p < 0.05$), and this was significantly different to C ($p < 0.05$). Testosterone-to-cortisol ratio increased in *SE* and Se ($p < 0.05$), whereas no change was observed in C. The intervention groups maintained or improved their physical performance during deployment, which is beneficial for operational readiness. However, the high interindividual variation observed in training adaptations highlights the importance of training individualization during prolonged military operations.

Key Words: readiness, performance, soldier, resistance and aerobic training, military

Introduction

A high level of operational readiness is a prerequisite for soldiers during deployments. However, optimal occupational performance may be challenged during prolonged military operations by a combination of stressors, such as sustained physical activity without optimized recovery, sleep deprivation, energy deficit, dehydration, climate, and cognitive and emotional stress (4,26,27,30). Such an environment may disrupt homeostatic regulation and with insufficient recovery, decreases in serum concentrations of anabolic hormones and increases in catabolic hormones may lead to increased muscle protein breakdown and thus, decreases in muscle mass and physical performance (5,16). Cumulatively, these stressors may reduce the ability to successfully fulfil operative duties. Even though the overall operative physiological stress may be lower during prolonged crisis management operations than during intensive combat operations (34), soldier readiness should still be maintained at a high level, because the security situation can change quickly in both types of operations.

Although several studies have reported negative changes in body composition, hormonal status, and physical performance following prolonged military field exercises (12), fewer studies have been published related to peace enforcement or crisis management operations (10,30,34). The findings of studies concerning military deployments are partly contradictory regarding changes in body composition and physical performance. However, decreases in aerobic fitness (10,25,40,43) and increases in fat mass (11,25,40) have been observed in several studies. These changes may also be inter-

Address correspondence to Kai Pihlainen, kai.pihlainen@mil.fi.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (http://journals.lww.com/nsca-jscr).

Journal of Strength and Conditioning Research 00(00)/1–10

related (32,44), and they may compromise occupational physical performance (33), increase the prevalence of injuries (43), and thereby have a negative impact on operative readiness.

Several studies have shown that superior physical performance is related to more efficient job performance within the military context (14,41). Because many typical military tasks require a combination of strength and endurance, it is logical to assume that through properly planned training, improvements in physical fitness variables would be associated with improved military performance and readiness (14,23,24). For example, regular strength training enhances neural input and motor control during voluntary muscle actions, and it also increases muscle cross-sectional area (18,21). Together, these changes lead to increases in maximal strength and the rate of force development, especially when explosive strength training is included (8), but also in movement economy during submaximal workload (2). These are important determinants of various military tasks, such as rushes and loaded running (33). In addition, typical military tasks, such as maximal lifting capacity and repetitive lifting performance, can be improved by strength training (45). Low-intensity endurance training increases not only the capillary network density but also the mitochondrial and aerobic enzyme content of the trained muscle cells. Together, these adaptations improve fat oxidation and acid-base balance during prolonged submaximal exercise (17) such as marching. High-intensity endurance training results in central adaptations, such as higher maximal cardiac output (15), and thus increases the functional reserves for load carriage by enabling soldiers to operate at a lower percentage of their maximal capacity (9). High-intensity endurance training and high-intensity functional training may also enhance combat readiness by eliciting similar psychophysiological responses to high-stress combat situations (42). On the other hand, prolonged combined endurance and strength training seems to lead to interference, especially in explosive force development (19). Moreover, a high volume of endurance type military training may interfere with optimal strength and power development (38). Nonetheless, improvements in the abovementioned physical fitness attributes likely lead to superior occupational performance and enhanced tolerance of mental and physical stress (29).

Thus, physical performance may be enhanced by optimally periodized strength and endurance training in various military environments (24). However, studies focusing on the effects of combined strength and endurance training during international military operations are scarce. Therefore, the purpose of the present study was to investigate the effects of different combinations of strength and endurance training on body composition, physical performance, and serum anabolic and catabolic biomarkers during a six-month crisis management operation in the Middle East.

Methods

Experimental Approach to the Problem

A longitudinal study design was used to investigate the effects of combined strength and endurance training on body composition, physical performance and, selected serum hormonal concentrations during deployment in South Lebanon. The military duties of the soldiers included patrolling and observing possible hostilities outside the military base, and maintenance and headquarter duties inside the base. The average ambient temperature was 22.3 ± 4.3° C during the study period (34). According to previous studies from the same study population, energy balance was maintained with a self-reported average energy intake of 2,400–2,500 kcal·d^{-1} (31), and objectively measured physical activity data suggest that the daily average physical work load was light (34). However, the soldiers were obligated to maintain operative readiness at all times throughout the deployment, which may have increased their psychological stress (34).

All measurements were conducted inside the military base in South Lebanon. To determine adaptations to combined strength and endurance training, baseline (PRE) measures of body composition, blood biomarkers and physical performance variables were recorded before block-randomizing (1) of soldiers into 3 training groups and a control group. The respective measurements were repeated 9 (MID) and 19 (POST) weeks after the baseline measurements. Because of operational demands, the soldiers were not able to attend all the measurements. In addition, 2 subjects voluntarily ended their participation in the study during the operation. Thus, the final study sample within each variable only consisted of soldiers who participated in all 3 measurements.

Subjects

A rotation unit of approximately 250 soldiers was given the possibility to take part in the present study. Before the deployment, a medical doctor physically examined these soldiers. The exclusion criteria for the deployment included health limitations requiring permanent medication, and a score lower than 2,300 meters in the 12-minute running test (7). Finally, 78 male soldiers volunteered for the PRE measurements. The means ± *SD*s and ranges for age, height, body mass (BM), and BM index (BMI) of the soldiers were 29 ± 8 (20–51) years, 1.80 ± 0.07 (1.65–1.99) *m*, 79 ± 8 (60–97) kg, and 24 ± 2 (18–33) kg·m^{-2}, respectively. The soldiers were informed of the study design and possible benefits and risks of the investigation. Thereafter, the soldiers gave their written informed consent to participate in the study. The study was conducted in accordance with the statement of the Ethical Committee of the Central Finland Health Care District and accepted by the Finnish Defence Forces.

Procedures

The study measurements have been described previously in detail (31–34). Briefly, body composition measurements and blood sampling were conducted after a minimum of 10-hours of overnight fasting at a military hospital. Body mass, BMI, skeletal muscle mass (SMM), and fat mass (FATM) were determined using segmental multifrequency bioimpedance analysis (InBody 720, Biospace, Seoul, South Korea). Blood samples were analyzed for serum testosterone (TES), sex-hormone binding globulin (SHBG), cortisol (COR), and insulin-like growth factor-1 (IGF1). Thereafter, the TES to COR (TES:COR) and TES to SHBG (TES:SHBG) ratios were calculated.

Physical performance was assessed on separate days with a minimum of 24 hours between the strength, endurance, and occupational tests. Soldiers were advised to avoid any training the day before each test session. Maximal isometric force of the lower (MVC_{lower}) and upper (MVC_{upper}) extremity extensor muscles were measured (28) bilaterally in a sitting position using an electromechanical dynamometer (University of Jyväskylä, Jyväskylä, Finland). The MVC_{lower} measurement (18) was performed in a horizontal leg press position with knee and hip angles fixed at 107 and 110°, respectively. For the MVC_{upper}

measurement, the handle bar was adjusted to the height of the shoulders so that elbow angle was maintained at 90°. In both measurements, soldiers were instructed to perform 3 maximal efforts with a minimum of 30 seconds recovery between trials. The trial with the highest force output was selected for further analysis. A standing long jump (SLJ) was used to assess power production of the lower extremities, whereas the maximal number of sit-ups and push-ups in one minute, and the maximum number of pull-ups (no time limit), were used to assess dynamic muscle endurance of the trunk and upper extremities. The soldiers were familiar with these tests, because they have also been used during basic military training. A test supervisor demonstrated the correct technique before each test and registered the test results.

Endurance performance was assessed using the 3000-m running test (3000-m). Soldiers were instructed to complete the test with maximal effort and in the shortest possible time, which was the outcome measure. Heart rate was recorded for training purposes using chest-strapped monitors (Memory belt, Suunto, Vantaa, Finland).

The military simulation test (MST) (33) was designed to assess occupational physical performance during crisis-management in soldiers. The 243-m test track consisted of common movements (rushes, jumps, changes in movement direction, and crawling) and military tasks (load carriage and casualty drag), which the soldiers may theoretically have to perform in an ambush during a patrol or convoy in the deployment area. The test was performed in the shortest possible time wearing regular patrolling gear (combat dress uniform, boots, combat vest, ammunition, body armor, and helmet) and carrying a replica assault rifle. The total mass of the outfit including the weapon was 22.5 ± 1.0 kg. Performance time was the outcome measure.

After the PRE measurements, all participating soldiers were block-randomized to one of the 3 intervention groups or the control group (**C**) and provided with a training diary. The diaries of the 3 intervention groups included the combined strength and endurance training program with illustrated instructions of the exercises to be performed twice a week, whereas the diary of group **C** included only blank pages with instructions about how to complete the diary. Pihlainen et al. (32) recently presented the general description of the training program. The individual exercises of the training program were similar between the 3 groups, but the strength-to-endurance training emphasis varied. Group ***SE*** performed 2 strength and 2 endurance training sessions in 2 weeks (i.e., 50% strength training). During the same time period, group **Se** performed 3 strength and one endurance training sessions (i.e., 75% strength training), whereas group **Es** performed 3 endurance and one strength training sessions (i.e., 25% strength training). Furthermore, to avoid possible detraining, the soldiers were encouraged to at least maintain the training volume that they were accustomed to before the operation, but to follow the training program and adjust their strength-to-endurance training emphasis to match the given program.

The first half of the study focused on low-to-moderate-intensity exercises. Thereafter, the training intensity was increased, and volume was decreased during the latter half of the study period. For hypertrophic (3–5 × 8–10 repetitions) and maximal strength (4 × 2–4 repetitions) training, soldiers were instructed to select weights for each exercise (e.g., squat, bench press, and deadlift), so that the last repetitions in each set would proceed as close to concentric failure as possible. The correct performance techniques of the exercises were demonstrated for the intervention groups and practiced before starting the training program. For endurance exercises, peak heart rate (HR_{peak}) was determined as the highest measured value during the 3000-m run using Firstbeat PRO analysis (Firstbeat Technologies, Jyväskylä, Finland). Because of the nature of the operation, the soldiers performed the exercises and completed the diaries throughout the study without supervision.

At the end of the follow-up, the training diaries were collected and analyzed. In some cases ($n = 15$), the self-reported training did not match with the emphasis of the given program. To provide more accurate results regarding training adaptations, these soldiers were regrouped into the group that most closely matched the predetermined strength-to-endurance training emphasis for the purpose of statistical analyses. The training diary data were analyzed for relative strength and endurance training frequency (sessions·wk^{-1}). In addition, endurance training was analyzed for volume (minutes·wk^{-1}) spent in different intensity zones (low-intensity <75% HR_{peak}, moderate-intensity 75–85 HR_{peak}, high-intensity >85 HR_{peak}), and strength training for the lower- and upper-body volume load (kg·wk^{-1}).

Statistical Analyses

Descriptive statistics (mean, *SD*, 95% confidence interval [CI], percentages) are reported where appropriate. Differences in within- and between-group changes, including the intervention groups combined (i.e., ***SE*** + **Se** + **Es**), were analyzed using linear regression models. The purpose of combining the intervention groups was to investigate the possible effects of providing a training program in general. Models were adjusted for the baseline value of a given outcome, and group **C** was the reference group. Outliers (z-score < −3.3 or >3.3) were detected and removed separately in each model. Unstandardized regression coefficients were expressed with 95% CI (Tables 2–4 and see Table 1, Supplemental Digital Content 1, http://links.lww.com/JSCR/A242). Moreover, relationships were examined between explanatory variables (body composition, physical performance, and biomarkers) and the relative change from PRE to POST for SMM, FATM, 3000-m, and MVC_{lower}. Analyses were performed using backward linear regression with stepping method criteria $p = 0.05$ for entering and $p = 0.10$ for removing. Explanatory variables with $p < 0.05$ in the univariate analysis were included for backward linear regression. Stata 15.1 for Windows was used for statistical analyses, and $p < 0.05$ was used to establish statistical significance.

Results

During the deployment, the average strength and endurance training frequency of the whole subject group was 3.2 ± 1.5 training sessions per week, of which 1.5 ± 0.9 sessions focused on strength and 1.7 ± 1.2 focused on endurance training. The most active groups in the average weekly training frequency were ***SE*** (3.3 ± 1.2) and **C** (4.0 ± 2.0). Self-reported group-wise statistics from the training diaries are presented in Table 1.

Body Mass increased by 0.5% during MID-POST in the combined (***SE***, **Se**, **Es**) intervention group and by 0.9% in group **C**. An increase of 1.3% in BM was also observed in ***SE*** during PRE-POST. Skeletal muscle mass increased by 1.0% in the combined group and by 2.3% in ***SE*** during PRE-POST (Figure 1). In ***SE***, a 1.6% increase in SMM was also observed during the first half of the study. In addition, FATM increased in the combined group by 3.4% during MID-POST. Between-group comparisons showed that the decrease in SMM during PRE-POST was higher

Table 1

Group-wise weekly mean (*SD*) and range of the training frequency, volume of endurance training and volume load of strength training in the combined strength and endurance training groups and the control group during the operation.*

	SE		Se		Es		C	
Training variables	Mean (*SD*)	Range	Mean (*SD*)	Range	Mean (*SD*)	Range	Mean (*SD*)	Range
Endurance training frequency (times)	1.5 (0.6)	0.6–3.1	0.7 (0.6)	0.0–2.0	2.2 (0.8)	0.8–3.5	2.2 (1.7)	0.0–6.5
Strength training frequency (times)	1.6 (0.8)	0.4–2.8	1.7 (0.5)	1.1–2.4	0.8 (0.4)	0.0–1.4	1.8 (1.4)	0.0–4.7
Total training frequency (times)	3.1 (1.2)	1.2–5.0	2.4 (0.7)	1.4–3.7	3.0 (1.1)	0.8–4.4	4.0 (2.0)	1.6–8.6
LIT (<75% HR_{peak}) volume (min)	62 (30)	30–151	50 (18)	30–81	78 (32)	36–144	55 (37)	20–125
MIT (75–85% HR_{peak}) volume (min)	48 (13)	24–67	49 (17)	30–72	43 (12)	27–60	43 (15)	21–65
HIT (>85% HR_{peak}) volume (min)	38 (22)	16–77	30 (11)	22–38	33 (12)	23–53	17 (5)	13–20
LB strength training volume load (×1,000 kg)	15.7 (7.2)	3.0–31.1	16.8 (6.5)	4.4–26.8	16.2 (7.0)	4.7–27.7	10.8 (7.6)	3.4–34.9
UB strength training volume load (×1,000 kg)	11.2 (4.5)	4.2–20.8	10.0 (3.0)	6.2–15.0	10.1 (4.2)	1.8–17.3	15.0 (9.3)	3.8–34.5

**SE* = 50% strength training group; Se = 75% strength training group; Es = 25% strength training group; C = control group; LIT = low-intensity endurance training; MIT = moderate-intensity endurance training; HIT = high-intensity endurance training; LB = lower body; UB = upper body.

in **Es** compared with the control group **C** (coef. −0.7 kg, 95% CI −1.3 to −0.1 kg, $p < 0.05$). Within-group changes in body composition are presented in Supplemental Digital Content 1 (see Table 1, http://links.lww.com/JSCR/A242).

Although no within-group changes were observed in 3000-m time, all groups improved their MST time between every measurement point (Figure 1). No differences in the changes in 3000-m or MST were observed between the intervention groups and group C. Standing long jump decreased by −2.4% and −1.9% in group C during PRE-POST and MID-POST, respectively. In addition, MID-POST decrements in SLJ performance were observed in the combined group (−1.5%) and *SE* (−2.6%). MVC_{lower} increased in the combined group by 12.8% during PRE-POST. Significant PRE-POST increases in MVC_{lower} were also observed in all individual intervention groups. Between-group analysis (reference group **C**) showed a higher PRE-POST increase in the combined intervention group (coef. 415 N, 95% CI 97–733 N, $p < 0.05$) and **Se** (coef. 611 N, 95% CI 181–1040 N, $p < 0.05$). In addition, when comparing with **C**, the increase in MVC_{lower} was significantly higher during PRE-MID in **Se** (coef. 632 N, 95% CI 232–1031 N, $p < 0.05$), whereas in **Es**, the respective change was higher during MID-POST (coef. 353 N, 95% CI 10–696 N, $p <$

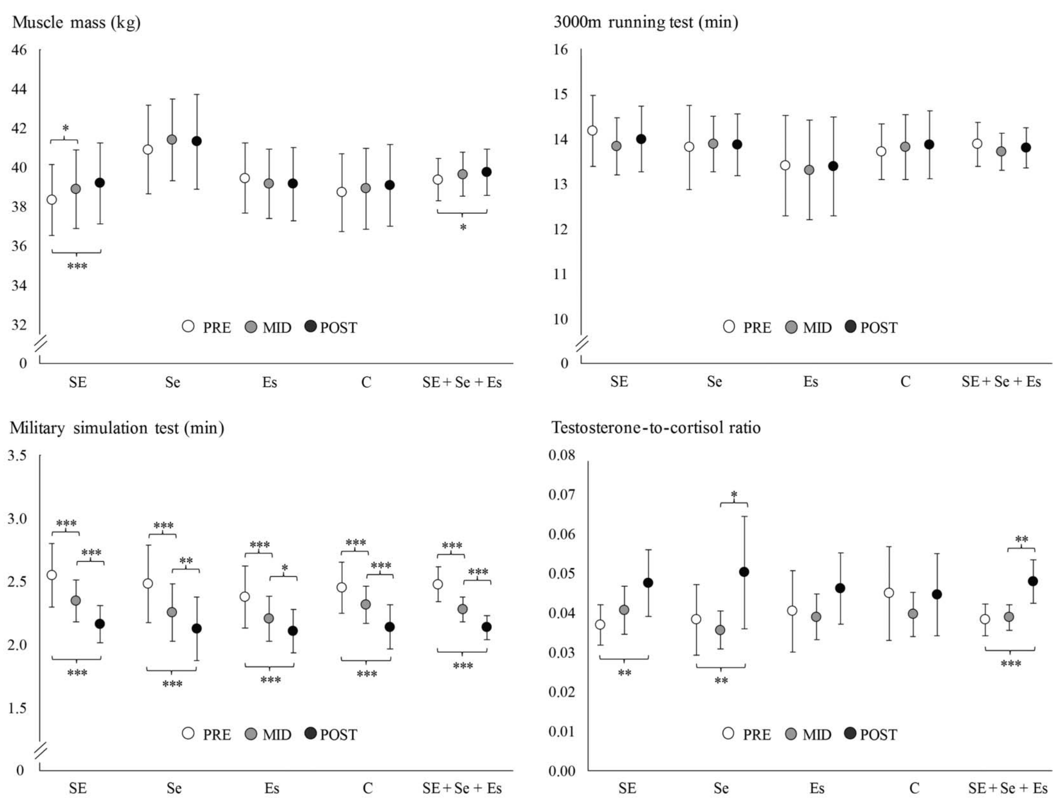

Figure 1. Within-group means and *SD*s for muscle mass, 3000-m running test, military simulation test and testosterone-to-cortisol ratio of the combined strength and endurance training groups and the control group during the operation. *$p < 0.05$; **$p < 0.01$; ***$p < 0.001$. Abbreviations: PRE, baseline; MID, first (9 weeks) follow-up measurement; POST, second (19 weeks) follow-up measurement; *SE*, 50% strength training group; Se, 75% strength training group; Es, 25% strength training group, C, control group.

0.05). MVC_{upper} increased during PRE-MID in the combined intervention group by 2.3%, whereas during MID-POST, a decrease of −3.4% was observed in **C**. Strength endurance tests (1-minute sit-ups and push-ups, maximum number of pull-ups) improved in all groups throughout the study. Within-group changes in physical performance are presented in Table 2.

Despite modest changes in the group mean values of body composition and some physical performance variables, interindividual variation in the magnitude and direction of changes was high (Figure 2).

TES increased by 10% and COR decreased by −8.7% in the combined intervention group during PRE-POST. TES also increased in **C** by 14.7% during PRE-MID and in **Es** by 16% during PRE-POST. The TES:COR ratio increased during the different phases of the study in the combined intervention group, **Se** and *SE*, but not in **C** or **Es** (Table 3). No differences were detected in the abovementioned changes between the intervention groups and group **C**. No within- or between-group changes were observed in IGF1. The TES:SHBG ratio increased during PRE-POST in all groups, whereas between-group comparisons showed a PRE-MID decrease in **Se** compared with **C** (coef. −0.12 $nmol{\cdot}L^{-1}$, 95% CI −0.24 to −0.01 $nmol{\cdot}L^{-1}$, $p < 0.05$), but during MID-POST, the respective change was positive (coef. 0.23 $nmol{\cdot}L^{-1}$, 95% CI 0.05–0.42 $nmol{\cdot}L^{-1}$, $p < 0.05$). Within-group changes in serum anabolic and catabolic biomarkers are presented in Table 3.

Multiple linear regression with backward elimination for the relative increase in SMM resulted in a relationship with a higher strength training frequency (coef. 1.283, 95% CI 0.495 to 2.072, $p = 0.002$), and relative decreases in MST time (coef. −0.176, 95% CI −0.294 to −0.057, $p = 0.014$) and TES:SHBG ratio (coef. 0.011, 95% CI 0.000 to 0.023, $p = 0.052$), which together explained 32% of the variance in the change in SMM (Adj. $R^2 = 0.317$). For increased FATM, a relationship was found with higher LB strength training volume load (coef. 1.058, 95% CI 0.335 to 1.780, $p = 0.005$) and increased 3000-m time (coef. 2.303, 95% CI 1.285 to 3.321, $p < 0.001$), with an adjusted R^2 of 0.514. Similarly, a relationship with the relative increase in MVC_{lower} was found with the relative increase in SLJ (coef. = 0.863, 95% CI −0.126 to 1.851, $p = 0.086$) and the respective decrease in MST time (coef. = −0.559, 95% CI −1.106 to −0.012, $p = 0.045$) (Adj. $R^2 = 0.105$). Finally, the relative change in 3000-m time was related to respective changes in BMI (coef. = 0.694, 95% CI 0.434 to 0.954, $p < 0.001$), MST time (coef. = 0.236, 95% CI 0.092 to 0.380, $p = 0.002$), and pull-up repetitions (coef. = −0.017, 95% CI −0.037 to 0.003, $p = 0.089$), as well as PRE 3000-m time (coef. = −0.016, 95% CI −0.027 to −0.004, $p = 0.007$), which together explained 68% of the variance in 3000-m time (Adj. $R^2 = 0.675$). Univariate linear regression results showing significant relationships with relative changes in 3000-m, MVC_{lower}, SMM, or FATM are presented in Table 4.

Discussion

The present study showed that intervention groups that performed a combined strength and endurance training program were able to maintain or improve all of the examined physical performance variables. Thus, from a physical performance point of view, the soldiers were able to maintain their operative readiness during the study period. In addition, both TES:COR and TES:SHBG ratios increased during PRE-POST and MID-POST in the combined intervention group, indicating a shift to a more anabolic status, and thus providing a favorable physiological milieu for positive training adaptations. MVC_{lower} improved more in the combined intervention group than in group **C**. Although nonsignificant changes within the training groups occurred according to the specificity principle of training, large interindividual variations in training adaptations were

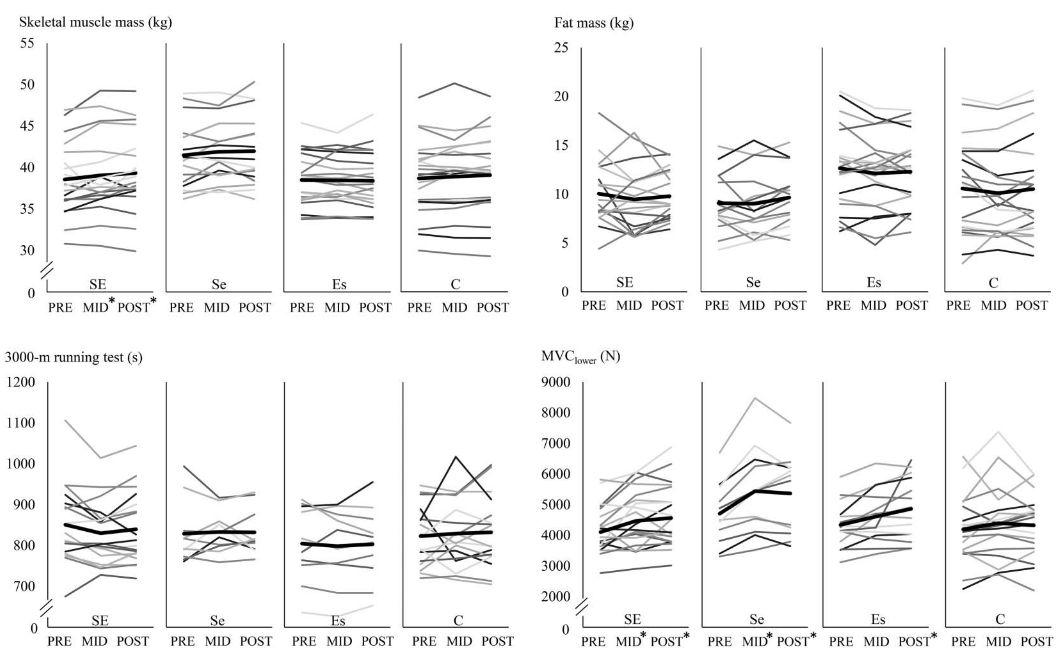

Figure 2. Individual and group mean (bolded line) changes in skeletal muscle mass, fat mass, maximal voluntary force of the lower extremities, and 3000-m running performance of the combined strength and endurance training groups and the control group during the operation. *Significant within-group change compared to PRE ($p < 0.05$). Abbreviations: PRE, baseline; MID, first (9 weeks) follow-up measurement; POST, second (19 weeks) follow-up measurement; *SE*, 50% strength training group; Se, 75% strength training group; Es, 25% strength training group, C, control group; MVC_{lower}, maximal voluntary force of the lower extremities.

Table 2
Physical performance variables (mean and *SD*) of the combined strength and endurance training groups and the control group at baseline (PRE), after 9 (MID) and 19 weeks (POST) and their changes within groups, based on unstandardized coefficients (Coef.) and 95% confidence intervals (CI) from linear regression models.*†

					Within groups		
	n	PRE	MID	POST	PRE-MID Coef. (95% CI)	PRE-POST Coef. (95% CI)	MID-POST Coef. (95% CI)
3000-m running test (min:s)							
SE	18	14:11 (1:36)	13:50 (1:17)	14:00 (1:29)	−0:16 (−0:36 to 0:04)	−0:08 (−0:27 to 0:11)	0:10 (−0:07 to 0:27)
Se	10	13:49 (1:18)	13:53 (0:52)	13:52 (0:57)	0:04 (−0:23 to 0:31)	0:03 (−0:22 to 0:28)	−0:01 (−0:23 to 0:21)
Es	10	13:25 (1:34)	13:18 (1:33)	13:23 (1:32)	−0:12 (−0:39 to 0:16)	−0:05 (−0:30 to 0:21)	0:04 (−0:19 to 0:27)
C	17	13:43 (1:12)	13:49 (1:24)	13:52 (1:28)	0:05 (−0:16 to 0:26)	0:09 (−0:11 to 0:28)	0:03 (−0:14 to 0:20)
SE, Se, Es	38	13:53 (1:31)	13:42 (1:15)	13:48 (1:22)	−0:10 (−0:23 to 0:04)	−0:04 (−0:17 to 0:08)	0:06 (−0:06 to 0:17)
Military simulation test (min:s)							
SE	15	2:33 (0:27)	2:21 (0:18)	2:10 (0:16)	**−0:11 (-0:14 to -0:07)**	**−0:22 (-0:26 to -0:17)**	**−0:11 (-0:15 to -0:06)**
Se	9	2:29 (0:24)	2:15 (0:18)	2:07 (0:20)	**−0:13 (-0:18 to -0:09)**	**−0:21 (-0:27 to -0:15)**	**−0:08 (-0:14 to -0:03)**
Es	11	2:22 (0:22)	2:12 (0:16)	2:06 (0:15)	**−0:13 (-0:17 to -0:08)**	**−0:18 (-0:24 to -0:13)**	**−0:06 (-0:11 to -0:01)**
C	12	2:27 (0:19)	2:19 (0:14)	2:08 (0:17)	**−0:09 (-0:13 to -0:04)**	**−0:19 (-0:24 to -0:14)**	**−0:11 (-0:15 to -0:06)**
SE, Se, Es	35	2:29 (0:25)	2:17 (0:17)	2:08 (0:16)	**−0:12 (-0:14 to -0:10)**	**−0:20 (-0:23 to -0:17)**	**−0:09 (-0:11 to -0:06)**
Standing long jump (cm)							
SE	18	234 (26)	237 (27)	231 (28)	2.8 (−0.9 to 6.6)	−3.2 (−7.8 to 1.4)	**−6.0 (-10.0 to -2.1)**
Se	12	238 (21)	238 (20)	236 (17)	−0.1 (−4.7 to 4.5)	2.1 (−7.8 to 3.5)	−2.0 (−6.9 to 2.8)
Es	15	238 (20)	241 (22)	238 (22)	3.1 (−1.0 to 7.3)	0.9 (−4.1 to 6.0)	−2.0 (−6.4 to 2.3)
C	19	236 (25)	235 (28)	230 (29)	−1.3 (−4.9 to 2.4)	**−5.6 (-10.0 to -1.1)**	**−4.4 (-8.3 to -0.6)**
SE, Se, Es	45	236 (22)	238 (23)	235 (25)	2.2 (−0.2 to 4.5)	−1.5 (−4.4 to 1.4)	**−3.6 (-6.1 to -1.1)**
Maximal voluntary force of the lower extremities (*N*)							
SE	19	4,216 (797)	4,547 (964)	4,651 (1,036)	**331 (83 to 580)**	**435 (168 to 702)**	97 (−130 to 324)
Se	12	4,168 (1,110)	4,997 (1,598)	4,908 (1,448)	**833 (520 to 1,146)**	**740 (404 to 1,077)**	−34 (−323 to 255)
Es	15	4,337 (735)	4,609 (828)	4,863 (982)	264 (−17 to 544)	**526 (225 to 827)**	256 (−0.1 to 511)
C	19	4,196 (1,081)	4,395 (1,191)	4,325 (1,013)	201 (−47 to 450)	129 (−138 to 397)	−98 (−326 to 131)
SE, Se, Es	46	4,243 (853)	4,684 (1,116)	4,787 (1,121)	**440 (272 to 608)**	**544 (372 to 716)**	115 (−31 to 262)
Maximal voluntary force of the upper extremities (*N*)							
SE	20	1,150 (261)	1,177 (263)	1,167 (263)	27 (−9 to 64)	18 (−23 to 60)	−9 (−42 to 25)
Se	11	1,121 (204)	1,142 (213)	1,163 (210)	20 (−29 to 69)	40 (−16 to 95)	18 (−27 to 64)
Es	15	1,199 (185)	1,228 (172)	1,204 (172)	33(-9 to 74)	12 (−36 to 59)	−19 (−58 to 20)
C	19	1,104 (253)	1,137 (250)	1,102 (232)	30 (−7 to 68)	−6 (−48 to 36)	**−37 (-72 to -3)**
SE, Se, Es	46	1,159 (223)	1,185 (223)	1,178 (220)	**27 (4 to 51)**	21 (−6 to 48)	−6 (−28 to 16)
Push-ups (repetitions in 1 minute)							
SE	20	40 (12)	41 (10)	44 (13)	0.7 (−2.0 to 3.5)	**4.3 (0.7 to 8.0)**	**3.6 (0.7 to 6.5)**
Se	11	37 (11)	41 (11)	46 (11)	2.7 (−1.0 to 6.4)	**8.7 (3.7 to 13.7)**	**5.9 (2.0 to 9.8)**
Es	15	44 (14)	46 (15)	50 (13)	2.1 (−1.1 to 5.3)	**6.7 (2.4 to 11.0)**	**4.8 (1.4 to 8.2)**
C	19	39 (13)	39 (12)	45 (16)	−0.2 (−3.0 to 2.6)	**5.7 (2.0 to 9.5)**	**5.9 (2.9 to 8.8)**
SE, Se, Es	46	41 (13)	42 (12)	47 (13)	1.6 (−0.2 to 3.4)	**6.2 (3.7 to 8.6)**	**4.5 (2.6 to 6.4)**
Sit-ups (repetitions in 1 minute)							
SE	20	45 (10)	47 (9)	48 (8)	**1.8 (0.3 to 3.4)**	**2.8 (0.8 to 4.7)**	0.9 (−0.6 to 2.4)
Se	12	46 (7)	47 (8)	49 (9)	0.6 (−1.4 to 2.7)	**2.7 (0.2 to 5.3)**	**2.1 (0.1 to 4.0)**
Es	15	48 (9)	50 (8)	50 (9)	**2.6 (0.8 to 4.4)**	**2.5 (0.2 to 4.8)**	−0.0 (−1.8 to 1.8)
C	19	46 (10)	46 (10)	48 (10)	−0.1 (−1.7 to 1.5)	1.8 (−0.3 to 3.8)	**1.8 (0.3 to 3.4)**
SE, Se, Es	47	46 (9)	48 (8)	49 (9)	**1.8 (0.8 to 2.8)**	**2.7 (1.4 to 3.9)**	0.9 (−0.1 to 1.9)
Pull-ups (repetition maximum)							
SE	20	9 (6)	11 (5)	12 (6)	**1.8 (0.7 to 2.8)**	**2.7 (1.4 to 4.0)**	0.9 (−0.0 to 1.9)
Se	12	9 (4)	10 (6)	12 (6)	0.8 (−0.5 to 2.2)	**2.9 (1.1 to 4.6)**	**2.0 (0.7 to 3.3)**
Es	15	12 (5)	13 (6)	15 (6)	**1.5 (0.3 to 2.7)**	**3.6 (2.0 to 5.1)**	**2.1 (0.9 to 3.2)**
C	19	9 (5)	11 (6)	12 (6)	**1.8 (0.8 to 2.9)**	**2.8 (1.4 to 4.2)**	0.9 (−0.1 to 2.0)
SE, Se, Es	47	10 (5)	11 (6)	13 (6)	**1.4 (0.8 to 2.1)**	**3.0 (2.2 to 3.9)**	**1.6 (0.9 to 2.2)**

*MID = first (9 weeks) follow-up measurement; POST = second (19 weeks) follow-up measurement; *SE* = 50% strength training group; Se = 75% strength training group; Es = 25% strength training group; C = control group.
†Bolded values, $p < 0.05$.

observed. Possible explanatory factors for not finding statistically significant differences include the low number of subjects in each study group and individual differences in baseline fitness levels, which should be taken into consideration when implementing a training program for soldiers during deployment.

Group ***SE***, who performed an equal distribution of strength and endurance training (49% strength training), was the only group that showed an increase in SMM while simultaneously maintaining endurance performance during the operation. Increases in muscle mass during military operations have been

Table 3

Serum anabolic and catabolic biomarkers (mean and *SD*) of the combined strength and endurance training groups and the control group at baseline (PRE), after 9 (MID) and 19 weeks (POST) and their changes within groups, based on unstandardized coefficients (Coef.) and 95% confidence intervals (CI) from linear regression models.*†

					Within groups		
	n	PRE	MID	POST	PRE-MID Coef. (95% CI)	PRE-POST Coef. (95% CI)	MID-POST Coef. (95% CI)
Testosterone (nmol·L^{-1})							
SE	19	15.4 (3.9)	16.4 (3.7)	16.7 (2.9)	0.7 (−0.8 to 2.3)	0.9 (−0.5 to 2.3)	−0.3 (−1.8 to 1.2)
Se	11	15.4 (2.5)	15.9 (2.4)	17.4 (2.7)	0.2 (−1.8 to 2.2)	1.7 (−0.2 to 3.6)	0.7 (−1.3 to 2.7)
Es	12	16.9 (7.1)	18.0 (4.9)	19.0 (5.1)	1.5 (−0.4 to 3.5)	**2.7 (0.9 to 4.5)**	1.5 (−0.4 to 3.4)
C	16	16.3 (4.5)	18.6 (4.6)	17.2 (3.4)	**2.4 (0.8 to 4.1)**	1.1 (−0.5 to 2.7)	−0.5 (−2.2 to 1.1)
SE, Se, Es	42	15.9 (4.7)	16.7 (3.8)	17.6 (3.6)	0.8 (−0.2 to 1.8)	**1.6 (0.6 to 2.6)**	0.5 (−0.5 to 1.5)
Cortisol (nmol·L^{-1})							
SE	19	431 (74)	421 (127)	385 (130)	−7 (−61 to 47)	−44 (−98 to 9)	−55 (−113 to 2)
Se	11	430 (97)	459 (95)	402 (156)	31 (−40 to 102)	−27 (−98 to 43)	−48 (−123 to 27)
Es	12	455 (114)	453 (132)	409 (118)	20 (−49 to 88)	−33 (−101 to 35)	−39 (−111 to 33)
C	16	401 (118)	465 (109)	412 (105)	42 (−17 to 102)	−2 (−61 to 57)	−39 (−102 to 23)
SE, Se, Es	42	438 (91)	440 (120)	396 (131)	10 (−26 to 47)	**−37 (-72 to -1)**	**−49 (-87 to -11)**
Insulin-like growth factor-1 (nmol·L^{-1})							
SE	19	27.9 (9.3)	25.2 (10.2)	23.9 (8.6)	−2.6 (−5.7 to 0.5)	−3.9 (−7.9 to 0.05)	−2.3 (−6.1 to 1.5)
Se	10	27.4 (10.4)	27.6 (9.5)	26.8 (13.9)	0.0 (−4.3 to 4.3)	−0.7 (−6.2 to 4.7)	−0.7 (−5.9 to 4.6)
Es	12	29.8 (10.1)	30.7 (8.3)	28.0 (10.2)	1.6 (−2.3 to 5.6)	−0.7 (−5.7 to 4.3)	−1.3 (−6.2 to 3.5)
C	16	26.0 (9.1)	27.3 (8.5)	27.5 (7.2)	0.8 (−2.7 to 4.2)	0.7 (−3.7 to 5.0)	0.2 (−3.9 to 4.3)
SE, Se, Es	41	28.3 (9.6)	27.4 (9.5)	25.8 (10.4)	−0.7 (−2.8 to 1.4)	−2.2 (−4.9 to 0.5)	−1.6 (−4.1 to 0.9)
Sex-hormone binding globulin (nmol·L^{-1})							
SE	19	31.0 (10.2)	25.7 (8.3)	23.6 (10.4)	**−6.0 (-9.3 to -2.6)**	**−7.9 (-11.7 to -4.0)**	−2.8 (−6.7 to 1.1)
Se	11	32.4 (11.8)	35.6 (8.6)	22.5 (8.9)	3.2 (−1.2 to 7.7)	**−9.9 (−14.9 to −4.8)**	**−12.5 (−17.5 to −7.5)**
Es	12	34.7 (14.9)	32.8 (11.9)	30.9 (16.6)	−0.8 (−5.0 to 3.5)	−3.0 (−7.8 to 1.9)	−1.6 (−6.3 to 3.1)
C	15	32.2 (11.9)	32.4 (10.1)	27.2 (9.8)	0.1 (−3.7 to 3.9)	**−5.0 (−9.3 to −0.7)**	**−5.0 (−9.2 to −0.8)**
SE, Se, Es	42	32.4 (11.9)	30.3 (10.3)	25.4 (12.4)	−2.1 (−4.5 to 0.4)	**−7.0 (−9.6 to −4.4)**	**−5.0 (−7.8 to −2.3)**
Testosterone-to-cortisol ratio							
SE	18	0.037 (0.010)	0.041 (0.012)	0.047 (0.017)	0.001 (−0.003 to 0.006)	**0.010 (0.003 to 0.016)**	0.008 (−0.001 to 0.016)
Se	11	0.038 (0.013)	0.036 (0.007)	0.050 (0.021)	−0.004 (−0.010 to 0.002)	**0.011 (0.003 to 0.020)**	**0.012 (0.002 to 0.023)**
Es	11	0.040 (0.015)	0.039 (0.009)	0.046 (0.014)	−0.001 (−0.007 to 0.005)	0.006 (−0.003 to 0.014)	0.007 (−0.004 to 0.018)
C	15	0.045 (0.022)	0.040 (0.010)	0.045 (0.019)	−0.001 (−0.007 to 0.004)	0.001 (−0.006 to 0.008)	0.005 (−0.004 to 0.015)
SE, Se, Es	40	0.038 (0.012)	0.039 (0.010)	0.048 (0.017)	−0.001 (−0.004 to 0.002)	**0.009 (0.005 to 0.014)**	**0.009 (0.003 to 0.14)**
Testosterone to sex-hormone binding globulin ratio							
SE	17	0.50 (0.17)	0.63 (0.13)	0.75 (0.26)	**0.11 (0.04 to 0.18)**	**0.25 (0.16 to 0.34)**	**0.14 (0.03 to 0.25)**
Se	10	0.52 (0.20)	0.45 (0.08)	0.79 (0.25)	−0.07 (−0.16 to 0.02)	**0.28 (0.16 to 0.39)**	**0.33 (0.18 to 0.47)**
Es	11	0.52 (0.13)	0.55 (0.14)	0.64 (0.18)	0.03 (−0.06 to 0.12)	**0.12 (0.01 to 0.24)**	0.09 (−0.04 to 0.23)
C	16	0.55 (0.23)	0.58 (0.21)	0.68 (0.29)	0.06 (−0.02 to 0.13)	**0.13 (0.04 to 0.23)**	0.10 (−0.01 to 0.21)
SE, Se, Es	38	0.51 (0.16)	0.56 (0.16)	0.73 (0.24)	0.04 (−0.01 to 0.09)	**0.22 (0.16 to 0.28)**	**0.17 (0.10 to 0.25)**

*MID = first (9 weeks) follow-up measurement; POST = second (19 weeks) follow-up measurement; *SE* = 50% strength training group; Se = 75% strength training group; Es = 25% strength training group; C = control group.
†Bolded values, $p < 0.05$.

reported previously in 2 studies (25,44). Group ***SE*** also improved MST time, MVC_{lower}, 1-minute sit-up and 1-minute push-up performance, and pull-up performance during the deployment. These changes were accompanied by a decrease in SHBG and increases in the TES:COR and TES:SHBG ratios. When comparing the training and performance outcomes between ***SE*** and **C**, it seems that ***SE*** achieved essentially the same training effects with a slightly lower training frequency but with a higher volume and higher relative share of high-intensity endurance training than group **C**. Strength and endurance training were emphasized rather equally in both groups. However, the lower-body strength training load was higher than the upper-body strength training load in ***SE*,** whereas it was the opposite in **C**.

Group **Se** spent 77% of weekly training frequency performing strength training, and improved the same physical performance test results as group ***SE***, whereas other variables remained unchanged. Compared with group **C**, a larger improvement was observed in lower body strength in **Se** during PRE-MID and PRE-POST. In addition, although the TES:SHBG ratio decreased more in **Se** during PRE-MID, it also increased during MID-POST when compared with group **C**. As was the case for ***SE***, strength training volume load in **Se** was higher for the lower body than the upper body, suggesting that the soldiers focused training on more important muscle groups from a military occupational performance perspective (3,14,33).

The same positive training adaptations as those observed in ***SE*** and **Se** were also observed in **Es**, which included 75% endurance training. This group improved MST time, MVC_{lower}, and all repetitive strength endurance test results during the study. Despite the different planned and reported endurance training volumes,

Table 4

Unstandardized regression coefficients (coef.) with *p*-values <0.05 for the PRE-POST relative change in 3,000 m running test performance (3000-m), maximal isometric force of the lower extremity extensor muscles (MVC_{lower}), muscle mass (SMM), and fat mass (FATM).*†

	Δ % 3000-m			Δ % MVC_{lower}			Δ % SMM			Δ % FATM		
	n	Coef.	*p*	n	Coef.	*p*	n	Coef.	*p*	n	Coef.	*p*
Strength training frequency (times·wk^{-1})	43	2.16	<0.001				60	0.98	0.009			
LB strength training load (×1,000 kg)										54	0.99	0.002
Δ PRE-POST body mass index (%)	54	0.75	<0.001									
PRE FATM (kg)	55	−0.41	0.034									
Δ PRE-POST FATM (%)	54	0.11	<0.001									
Δ PRE-POST SLJ (%)				64	1.10	0.012						
Δ PRE-POST MST (%)	49	0.35	<0.001	58	−0.61	0.028	62	−0.11	0.027	62	0.83	0.009
Δ PRE-POST sit-up (%)	53	−0.10	0.042							72	−0.43	0.024
Δ PRE-POST pull-up (%)	53	−0.03	0.020									
PRE MVC_{lower} (N)	55	0.0013	0.046									
Δ PRE-POST MVC_{lower} (%)	53	−0.09	0.045									
Δ PRE-POST MVC_{upper} (%)							71	0.091	0.024			
Δ PRE-POST 3000-m (%)										64	1.87	0.001
Δ PRE-POST SHBG (%)							50	−0.029	0.021			
Δ PRE-POST TES:SHBG (%)	50	0.019	0.041									
PRE IGF1 (nmol·L^{-1})										50	−0.69	0.012
Δ PRE-POST IGF1 (%)										50	−2.15	0.003

*PRE = baseline measurement at the beginning of the operation; POST = final measurement at the end of the operation; LB = lower body; FATM = fat mass; kg = kilogram; SLJ = standing long jump; MST = military simulation test; MVC_{upper} = maximal isometric force of the upper extremity extensor muscles; SHBG = Sex-hormone binding globulin, TES:SHBG = Testosterone to sex-hormone binding globulin ratio; IGF1 = Insulin-like growth factor-1.
†Explanatory variables are adjusted for the baseline value of the outcome.

all groups were able to maintain their endurance performance during the operation. This is important especially from the perspective of the groups with lower endurance training volume, given that high mechanical loading from running may increase musculoskeletal injury risk and thereby reduce operative workforce during deployment (37). Overall, maintenance of endurance performance may be considered a positive adaptation during a military operation, because in many prior studies aerobic fitness has been shown to decrease during deployment (10,25,40,43).

Currently, there are no military standards for physical training during deployment in soldier populations. Because the soldiers in group **C** were not provided with any additional tools for improving physical performance, their exercise behavior and changes in body composition and physical performance reflect individual preferences, and are comparable to previous samples of military operation studies. Group **C** improved PRE-POST military-specific performance (MST) and muscle endurance of the trunk and arm flexors while maintaining endurance performance and body composition. Many previous studies of military operations have demonstrated positive changes in muscle endurance (10,37,40,44), whereas decrements in endurance performance have also been observed (10,26,41,44). In the present study, endurance performance was maintained at least at baseline levels. Similar results were reported after a 4-month military operation in Chad by Rintamäki et al. (36), and after a 6-month operation in Afghanistan by Fallowfield et al. (11). Interestingly, the highest average training frequency (4 ± 2 times per week), with 46% of the training sessions focusing on strength training, was reported in group **C**. On the other hand, the average lower body strength training volume load (kg·wk^{-1}) of group **C** was the lowest, and the respective upper body training volume load was the highest among all groups of this study. This suggests that the training programs performed by the intervention groups may have emphasized lower body strength training more during the operation. Despite the higher overall upper-body strength training volume, no PRE-POST changes but a decrease in MID-POST were observed in MVC_{upper} performance of group **C**. Furthermore, all other groups except **C** improved their lower-body strength during the study, whereas power of the lower extremities, assessed by SLJ, decreased only in group **C** between PRE and POST. This is important to note, given that lower body strength and power are very important physical abilities of a combat-armed soldier (3). It is possible that individual preferences do not necessarily reflect optimal training habits among tactical athletes, which may increase the risk of injury while on-duty or during training (35). These findings emphasize the role of strength and conditioning professionals in the prescription of periodized of strength and endurance training programs during crisis-management operations.

As mentioned earlier, strength and endurance constitute the basis of soldier physical performance (14,24,29). Optimally periodized combined strength and endurance training may improve muscle strength and endurance performance simultaneously without interference effects (19). It must be taken into consideration that higher (>3 times·wk^{-1}) endurance training frequency and volume, especially with high overall training volume, may have a negative influence on strength performance outcomes during concurrent training (38,46). In the present study, no interference effect on strength development was observed, but a weak correlation between increased strength training in relation to endurance training and increased 3000-m time was found in a previous study consisting of the same study sample (32). Similarly, a relationship between higher strength training frequency and increased 3000-m time was found with linear regression analyses in the present study. Increased 3000-m time was also associated with increased FATM. Thus, decreases in aerobic fitness and increases in fat mass, which have been observed in several military operation studies (11,25,40), seem to be at least partly linked. Furthermore, a relationship was observed between increased FATM and decreased MST time, which could be used from a physical performance perspective as an indirect measure of military readiness.

It has been suggested that during deployment, the training objective should be to maintain fitness levels, which can be achieved by performing strength training twice weekly, accompanied by anaerobic-aerobic endurance training one or 2 times per week (13). However, psychological stress induced by operative duties may accumulate internal training load, and should be taken into consideration in the daily training plan from a recovery perspective (13). In addition, other intrinsic factors such as age, individual fitness level and training status may affect internal training load, and thereby training adaptations (21,32). In the present study, baseline body composition (e.g., higher FATM) and physical performance (e.g., weaker MVC_{lower} result) showed weak but statistically significant relationships with training outcomes, namely, larger improvements in 3000-m time. Another study in conscripts (22) showed that despite the same standardized weekly program during basic military training, the highest internal training loads and the largest training adaptations were found in individuals with the lowest baseline fitness level and vice versa—the fittest individuals experienced the lowest internal training load. These results are in line with studies showing that untrained individuals seem to benefit from concurrent training similarly compared with training each mode separately, whereas individuals with a longer training background seem to be more susceptible to interference effects (6). In the present study, large variability in training adaptations may have been at least partly explained by the inadequate individualization of the training, which was because of randomization of the training groups. A previous study using the same study sample showed that soldiers with higher baseline levels of FATM and lower levels of SMM and lower-body strength were more likely to improve their endurance performance during the military operation (32). Obviously, individualization of training is challenging in the military context, because the number of soldiers is typically high within the same training session. Moreover, training possibilities are limited in many hazardous deployment environments.

All 3 measurement points of the present study were conducted in the deployment area during the crisis management operation. In most previous military operation studies, the measurements were performed before and after the deployment, and thus the delay between measurements and the deployment may have influenced the results. In addition, 3 measurement points provide valuable information about possible fluctuations in variables of interest within the follow-up period. A limitation of this study was low adherence to the randomly selected training program. As mentioned, 15 soldiers did not follow the prescribed strength-to-endurance emphasis. To analyze group changes reliably, modifications to the original group division had to be performed according to self-reported training diaries. On the other hand, this is an important finding to be taken into consideration when implementing an unsupervised training program. Another option would be supervised training sessions, which may be challenging during a military operation with rotating work shifts. In addition, one limitation was not using the gold standard in vivo methods to measure body composition (e.g., hydrostatic weighing or dual energy X-ray absorptiometry) and aerobic fitness (e.g., direct maximal oxygen consumption measurement). Implementing the study during an international crisis management operation limited the possibility to select the best possible measurement methods, and created logistical challenges regarding measurement devices and personnel. Finally, dietary control might have provided further support for interpretation of training adaptations.

Practical Applications

The present findings suggest that operational demands did not increase the internal training load of soldiers excessively during the present study, which enabled the maintenance or development of physical performance during the deployment. Maintenance of baseline BM and composition and endurance performance during deployment was achieved by performing combined strength and endurance training, on average 3 times a week. This average is in line with previous deployment studies (36,44) and recommended training frequency guidelines in this setting (13). During the follow-up period, the training group that performed an even volume of combined strength and endurance training (***SE***) was the only group to increase muscle mass, while simultaneously improving the same physical performance outcomes as the other intervention groups. Although individualized training prescription should take into account factors such as baseline fitness level, provision of a combined strength and endurance training program should encourage soldiers to focus training more on qualities related to their task demands, such as strength and power of the lower extremities. Finally, compulsory physical training or other supervised physical activities may help less fit and less motivated soldiers to avoid decrements in physical performance during longer operations.

Acknowledgments

The authors appreciate the financial support of the Centre for Military Medicine, Scientific Advisory Board for Defence (MATINE), the Defence Support Foundation and, the contribution of the participating soldiers.

References

1. Altman DG, Bland JM. How to randomize. *BMJ* 329: 703–704, 1999.
2. Balsalobre-Fernández C, Santos-Concejero J, Grivas GV. Effects of strength training on running economy in highly trained runners: A systematic review with meta-analysis of controlled trials. *J Strength Cond Res* 30: 2361–2368, 2016.
3. Billing DC, Silk AJ, Tofari PJ, Hunt AP. Effects of military load carriage on susceptibility to enemy fire during tactical combat movements. *J Strength Cond Res* 29(Suppl 11): S134–S138, 2015.
4. Campbell DJ, Nobel O. Occupational stressors in military service: A review and framework. *Mil Psychol* 21(Suppl 2): S47–S67, 2009.
5. Church DD, Gwin JA, Wolfe RR, Pasiakos SM, Ferrando AA. Mitigation of muscle loss in stressed physiology: Military relevance. *Nutrients* 11: 1703, 2019.
6. Coffey VG, Hawley JA. Concurrent exercise training: Do opposites distract? *J Physiol* 595: 2883–2896, 2017.
7. Cooper KH. A means of assessing maximal oxygen intake. Correlation between field and treadmill testing. *JAMA* 203: 201–204, 1968.
8. Davies TB, Kuang K, Orr R, Halaki M, Hackett D. Effect of movement velocity during resistance training on dynamic muscular strength: A systematic review and meta-analysis. *Sports Med* 47: 1603–1617, 2017.
9. Drain J, Billing D, Neesham-Smith D, Aisbett B. Predicting physiological capacity of human load carriage - a review. *Appl Ergon* 52: 85–94, 2016.
10. Dyrstad SM, Miller BW, Hallén J. Physical fitness, training volume, and self-determined motivation in soldiers during a peacekeeping mission. *Mil Med* 172: 121–127, 2007.
11. Fallowfield JL, Delves SK, Hill NE, et al. Energy expenditure, nutritional status, body composition and physical fitness of Royal Marines during a

6-month operational deployment in Afghanistan. *Br J Nutr* 112: 821–829, 2014.

12. Friedl KE, Moore RJ, Hoyt RW, et al. Endocrine markers of semistarvation in healthy lean men in a multistressor environment. *J Appl Physiol* 88: 1820–1830, 2000.
13. Haff GG. Periodization for tactical populations. In: Alvar B, Sell K, Deuster P, eds. *NCSA's Essentials of Tactical Strength Training and Conditioning*. Champaign, IL: Human Kinetics, 2017. pp. pp181–205.
14. Hauschild VD, DeGroot DW, Hall SM, et al. Fitness tests and occupational tasks of military interest: A systematic review of correlations. *Occup Environ Med* 74: 144–153, 2017.
15. Helgerud J, Høydal K, Wang E, et al. Aerobic high-intensity intervals improve VO2max more than moderate training. *Med Sci Sports Exerc* 39: 665–671, 2007.
16. Henning P, Park B-S, Kim J-S. Physiological decrements during sustained military operational stress. *Mil Med* 176: 991–997, 2011.
17. Holloszy JO, Coyle EF. Adaptations of skeletal muscle to endurance exercise and their metabolic consequences. Review. *J Appl Physiol Respir Environ Exerc Physiol* 56: 831–838, 1984.
18. Häkkinen K, Alen M, Komi PV. Changes in isometric force and relaxation time, electromyographic and muscle fibre characteristics of human skeletal muscle during strength training and detraining. *Acta Physiol Scand* 125: 573, 1985.
19. Häkkinen K, Alen M, Kraemer WJ, et al. Neuromuscular adaptations during concurrent strength and endurance training versus strength training. *Eur J Appl Physiol* 89: 42–52, 2003.
20. Häkkinen, K., Komi, P.V., Alen, M. Effect of explosive type strength training on isometric force- and relaxation time, electromyographic and muscle fibre characteristics of leg extensor muscles. *Acta Physiologica Scandinavica 125, 587 600, 1985.*
21. Impellizzeri FM, Marcora SM, Coutts AJ. Internal and external training load: 15 Years on. *Int J Sports Physiol Perform* 14: 270–273, 2019.
22. Jurvelin H, Tanskanen-Tervo M, Kinnunen H, Santtila M, Kyröläinen H. Training load and energy expenditure during military basic training period. *Med Sci Sports Exerc* 52: 86–93, 2020.
23. Kraemer WJ, Vescovi JD, Volek JS, et al. Effects of concurrent resistance and aerobic training on load-bearing performance and the Army physical fitness test. *Mil Med* 169: 994–999, 2004.
24. Kyröläinen H, Pihlainen K, Vaara JP, Ojanen T, Santtila M. Optimising training adaptations and performance in military environment. *J Sci Med Sport* 21: 1131–1138, 2018.
25. Lester ME, Knapik JJ, Catrambone D, et al. Effect of a 13-month deployment to Iraq on physical fitness and body composition. *Mil Med* 175: 417–423, 2010.
26. Martin K, McLeod E, Périard J, et al. The impact of environmental stress on cognitive performance: A systematic review. *Hum Factors* 61: 1205–1246, 2019.
27. Martin K, Périard J, Rattray B, Pyne DB. Physiological factors which influence cognitive performance in military personnel. *Hum Factors* 62: 93–123, 2020.
28. McMaster DT, Gill N, Cronin J, McGuigan M. A brief review of strength and ballistic assessment methodologies in sport. *Sports Med* 44: 603–623, 2014.
29. 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 Cond Res* 29(Suppl 11): S216–S220, 2015.
30. Nindl BC, Castellani JW, Warr BJ, et al. Physiological employment standards III: Physiological challenges and consequences encountered during international military deployments. *Eur J Appl Physiol* 113: 2655–2672, 2013.
31. Nykänen T, Pihlainen K, Santtila M et al. Diet macronutrient composition, physical activity, and body composition in soldiers during 6 Months deployment. *Mil Med* 184: e231–e237, 2019.
32. Pihlainen K, Häkkinen K, Santtila M, Raitanen J, Kyröläinen H. Differences in training adaptations of endurance performance during combined strength and endurance training in a 6-month crisis management operation. *Int J Environ Res Public Health* 17: 1688, 2020.
33. Pihlainen K, Santtila M, Häkkinen K, Kyröläinen H. Associations of physical fitness and body composition characteristics with simulated military task performance. *J Strength Cond Res* 32: 1089–1098, 2018.
34. Pihlainen K, Santtila M, Vasankari T, Häkkinen K, Kyröläinen H. Evaluation of occupational physical load during 6-month international crisis management operation. *Int J Occup Med Environ Health* 31: 185–197, 2018.
35. Pryor RR, Colburn D, Crill MT, Hostler DP, Suyama J. Fitness characteristics of a suburban special weapons and tactics team. *J Strength Cond Res* 26: 752–757, 2012.
36. Rintamäki H, Kyröläinen H, Santtila M, et al. From the subarctic to the tropics: Effects of 4-month deployment on soldiers' heat stress, heat strain, and physical performance. *J Strength Cond Res* 26(Suppl 2): S45–S52, 2012.
37. Roy TC, Knapik JJ, Ritland BM, Murphy N, Sharp MA. Risk factors for musculoskeletal injuries for soldiers deployed to Afghanistan. *Aviat Space Environ Med* 83: 1060–1066, 2012.
38. Santtila M, Kyröläinen H, Häkkinen K. Changes in maximal and explosive strength, electromyography, and muscle thickness of lower and upper extremities induced by combined strength and endurance training in soldiers. *J Strength Cond Res* 23: 1300–1308, 2009.
39. Sedliak M, Sedliak P, Vaara JP. Effects of 6-month military deployment on physical fitness, body composition, and selected health-related biomarkers. *J Strength Cond Res* 2019. doi: 10.1519/JSC.0000000000002885. [Epub ahead of print].
40. Sharp MA, Knapik JJ, Walker LA, et al. Physical fitness and body composition after a 9-month deployment to Afghanistan. *Med Sci Sports Exerc* 40: 1687–1692, 2008.
41. Sharp M, Patton J, Vogel J. A database of physically demanding tasks performed by U.S. army soldiers. Natick MA: Military Performance Division. U.S. Army Research Institute of Environmental Medicine. Technical Report T98, 1998. p. 1–42.
42. Tornero-Aguilera JG, Clemente-Suárez VJ. Resisted and endurance high intensity interval training for combat preparedness. *Aerosp Med Hum Perform* 90: 32–36, 2019.
43. Warr BJ, Heumann KJ, Dodd DJ, Swan PD, Alvar BA. Injuries, changes in fitness, and medical demands in deployed National Guard soldiers. *Mil Med* 177: 1136–1142, 2012.
44. Warr BJ, Scofield DE, Spiering BA, Alvar BA. Influence of training frequency on fitness levels and perceived health status in deployed National Guard soldiers. *J Strength Cond Res* 27: 315–322, 2013.
45. Williams AG, Rayson MP, Jones DA. Resistance training and the enhancement of the gains in material-handling ability and physical fitness of British Army recruits during basic training. *Ergonomics* 45: 267–279, 2002.
46. Wilson JM, Marin PJ, Rhea MR, et al. Concurrent training: A meta-analysis examining interference of aerobic and resistance exercises. *J Strength Cond Res* 26: 2293–2307, 2012.