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Tommi Ojanen

Effect of Prolonged Military Field Training and Different Physical Training Programmes on Physiological Responses and Physical Performance in Soldiers

UNIVERSITY OF JYVÄSKYLÄ
FACULTY OF SPORT AND
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ABSTRACT

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To fulfil their required missions, soldiers need adequate physical fitness and sufficient ability to move in different terrains. During the Finnish conscript service, the physical fitness of conscripts can be improved to the required occupational level using different military tasks. Carefully planned, periodized, and progressive physical fitness training can help soldiers to reach different required occupational task levels before the end of the military service.

The present study was carried out in two phases. The first phase consisted of a 21-day military field training, which concentrated on the effects of prolonged military field training on the physiological characteristics of the soldiers. The second phase included a 12-week physical training intervention, which focused on the effects of different types of physical training and the physiological characteristics of the soldiers.

The first part of the study showed that physical activity during prolonged military training mainly consists of long duration and low intensity aerobic work, which includes load carriage and lifting of different amounts of loads. When looking at the combat phase of the exercise, it was observed that speed and anaerobic performance are also required. The daily occupational duties of a soldier mainly consist of low intensity physical work, and therefore it is important that training regimens would provide sufficient variation in physical intensity for the soldiers. The training intervention study showed that strength training in soldiers needs to be systematically planned and supervised. Interval training was found to efficiently improve endurance performance in soldiers. Additionally, it was found that systematic and well-planned strength training is connected to the development of strength, power, and speed, as well as to the development of motor skills.

The results of the present study showed that task-specific and traditional strength training did not differ in regard to the conferred gains in strength; however, both training groups improved strength abilities significantly more than the group that did traditional military physical training. In the future, it is important to include more task-specific strength or traditional strength training into military physical training programs to enhance occupational performance in soldiers.

Keywords: military, soldier, training, physical activity

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TIIVISTELMÄ (FINNISH ABSTRACT)

Ojanen, Tommi
Sotilaan kuormittuminen pitkäkestoisessa taisteluharjoituksessa sekä voima- ja kestävyysharjoittelun vaikutus fyysiseen toimintakyyn ja kehon koostumukseen.
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Suorittaakseen tehtävänsä menestyksekkäästi sotilas tarvitsee sekä hyvää fyysistä suorituskykyä että maastossa liikkumisen taitoa. Varusmiespalveluksen aikana nuoren suomalaisen miehen fyysistä suorituskykyä pystytään parantamaan oikeanlaisella harjoittelulla eri sotilastehtävien vaatimusten mukaisesti. Oikein suunnitellulla, systemaattisesti jaksotetulla ja riittävän kuormittavalla liikuntakoulutuksella pystytään vaikuttamaan kehittävästi sotilaan fyysiseen toimintakykyyn eri sotilastehtävien vaatimusten mukaan.

Tutkimus toteutettiin kahdessa vaiheessa siten, että ensimmäinen vaihe sisälsi 21 vuorokauden mittaisen maastoharjoituksen, jolloin selvitettiin pitkäkestoisen taisteluharjoituksen vaikutuksia sotilaan fyysiseen toimintakykyyn. Toisen tutkimusvaiheen tavoitteena oli kartoittaa, miten eri tavoilla painotettu liikuntakoulutus vaikuttaa varusmiesten fyysisten ominaisuuksien kehittymiseen.

Tutkimuksen ensimmäisessä vaiheessa havaittiin, että sotilaan työ on pitkäkestoista ja matalatehoista aerobista työtä, joka vaatii kuitenkin raskaidenkin taakkojen kantamista ja nostamista. Taisteluvaiheessa tarvitaan myös nopeutta ja anaerobista suorituskykyä. Koska sotilaan päivittäiset tehtävät sisältävät paljon matalatehoista työtä, on tärkeää, että liikuntakoulutuksessa pystyttäisiin antamaan erilaisia ärsykkeitä elimistölle. Toisessa vaiheessa toteutetun harjoittelututkimuksen tuloksena todettiin, että sotilaan voimaharjoittelun tulee olla suunnitelmallista ja ohjattua. Sotilaiden kestävyyden taas on osoitettu kehittyvän tehokkaasti intervallityyppisellä harjoittelulla. Säännöllisen ja suunnitelmallisen voimaharjoittelun tiedetään olevan yhteydessä sekä lihaksiston että sen tukiosien, jänteiden ja sidekudosten voiman kehittymiseen, tehon ja nopeuden lisääntymiseen ja motorisen suorituskyvyn paranemiseen.

Tutkimuksen tulosten perusteella voidaan todeta, että tehtäväkohtaiseen ja perinteiseen voimaharjoitteluun painottuneiden ryhmien välillä ei ollut eroja voimaominaisuuksien kehittymisessä, mutta kummassakin ryhmässä varusmiehet kehittyivät selvästi enemmän kuin voimassa olevan erikoiskoulutuskauden fyysistä harjoitusohjelmaa noudattaneet.

Avainsanat: armeija, sotilas, harjoittelu, fyysinen aktiivisuus

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LIST OF ORIGINAL PUBLICATIONS

The present thesis is based on the following original articles, which are referred to in the text by their Roman numerals.

I Ojanen, T., Häkkinen, K., Vasankari, T., Kyröläinen, H. 2018. Changes in physical performance during 21 d of military field training in warfighters. Military Medicine 183 (5-6), e174–e181.

II Ojanen, T., Kyröläinen, H., Igendia, M., Häkkinen, K. 2018. Effect of prolonged military field training on neuromuscular and hormonal responses and shooting performance in warfighters. Military Medicine 183 (11-12), e705–e712.

III Ojanen, T., Kyröläinen, H., Kozharskaya, E., Häkkinen, K. 2020. Changes in strength and power performance and serum hormone concentrations during 12 weeks of task-specific or strength training in conscripts. Physiological Reports 8 (9), e14422.

IV Ojanen, T., Häkkinen, K., Hanhikoski, J., Kyröläinen, H. 2020. Effects of task-specific and strength training on simulated military task performance in soldiers. International Journal of Environmental Research and Public Health 17 (21), 8000.

The author of this thesis, who is the first author of the abovementioned publications, was mainly responsible for designing the studies, leading and participating in the collection of data during the field measurements. The author was also responsible for data analyses, interpreting results, preparing the manuscripts, and managing the review process during publication procedures.

CONTENTS

1 INTRODUCTION

It is a wellknown fact that every soldier needs muscle strength and aerobic capacities to fullfill his/her occupational task requirements. Regular physical activity and proper daily health-related behaviours are fundamental for both physical and mental well-being as well as for performance optimization in the battefield. Soldiers need high physical, psychological, and cognitive readiness to be successfull in their everyday occupational tasks.

The modern battlefield sets high demands and challenges to soldiers' physical and psychological domains (Henning et al. 2011; Nindl et al. 2013). Although the development of technology has relieved some of the physical and psychological burden on the battlefield, the overall load placed on soldiers has increased and the time for recovery has decreased (Knapik et al. 2012). In addition, energy and fluid deficits (Alemany et al. 2008; Margolis et al. 2013; Richmond et al. 2014), sleep deficits (Grandou et al. 2019), environmental issues (cold, heat, altitude, pollution) (Bakker-Dyos et al. 2016; Korzeniewski et al. 2013; Parsons et al. 2019), injuries (Chester et al. 2013) and psychological issues (Flanagan et al. 2012) can all have negative effects on soldiers' performance in the battlefield. As a consequence of all these stressors, it is essential for soldiers to have adequate physical and psychological status to manage all the occupational tasks they have to perform (Flanagan et al. 2012; Friedl et al. 2015; Knapik et al. 2012).

Soldiers daily work includes physically demanding occupational tasks (Ainsworth et al. 2000; Sperlich et al. 2011). Typical occupational tasks include lifting and lowering, pushing and carrying different objects (25 to 45 kg) and marching with loads (25 to 35 kg). Knapik et al. (2012) have indicated that the marching distances have shortened and the physical intensity has increased. In addition, according to Szivak and Kraemer (2015), the modern battlefield necesitates heavy load carriage and more anaerobic work periods, which increases the demands on soldiers physical performance and highlights the importance of strength and power training in soldiers. Increased lower body strength has been found to positively influence marching performance, and increased upper body strength improves load carriage (Harman et al. 2008; Nindl et al. 2002; Welsh et al. 2008). Both endurance and strength are needed in the battlefield. This is important to take into account when designing physical training programs for soldiers.

The need for suitable physical training programs, especially focusing on strength and power together with endurance, is essential for improving soldiers' physical performance. However, excessive amounts of strength or endurance training interferes with the optimal development of soldiers' overall physical abilities. Physical training programs should aim to improve soldiers' physical abilites to the sufficient level without over-training, considering there is no time for recovery periods during intense military operations. Soldiers need to be in good physical and psychological shape to make decisions quickly and responsibly, even when they are in sleep deprivation, energy deficit or physically fatiqued. Previous studies have shown that good physical performance is connected to resilience, as well as psychological and cognitive performance (Deuster & Silverman 2013; Martin et al. 2020). When developing physical training programs for soldiers, it is important to find an optimal balance between physical training and military specific training to avoid overreaching and training interference. A sufficient physical performance level helps the soldier to recover faster and to be more prepared for different tasks (Nindl et al. 2007; Sporis et al. 2012).

The present dissertation aimed to investigate the effects of prolonged military field training on soldiers' anthropometric, physical and hormonal concentration values (study 1). The second aim of the present dissertation was to study the changes in strength and power performance and serum hormone concentrations induced by 12 weeks of task-specific or general strength training and the effects of these interventions on simulated military task performance in soldiers (study 2).

2 REVIEW OF THE LITERATURE

2.1 Factors affecting physical performance in soldiers during military training

The overall physical demands in military occupational duties call for sufficient preparation before deployment. Carrying out common military tasks alone will by no means provide sufficient stimulus for the cardiorespiratory and neuromuscular systems to sustain or enhance physical fitness to the needed level. Drain & Reilly (2019) showed that proper physical training could improve military occupational performance and decrease musculoskeletal injury risk. Pre-operation military field training exposes soldiers to different physical, mental/cognitive and environmental stressors. Occupational physical tasks (e.g., lifting heavy objects, crawling, running, jumping, patrolling long distances with heavy loads in different terrains and performing explosive movements) are repeated several times during a normal training day (Hendricksson et al. 2010). Soldiers are also exposed to many other physiological stressors during military field training including physical fatigue (Nindl et al. 2007), sleep deprivation (Grandou et al. 2019) and insufficient energy and fluid intake (Church et al. 2019; Margolis et al. 2013; Murphy et al. 2018). How all these stressors effect soldiers' neuromuscular performance, hormonal responses, task specific performance, and deployment ability are of vital importance to commanders.

All these stressors make it challenging to construct effective and achievable physical training programs for soldiers. Physical performance can be improved by modifying the level of physical activity as well as the type and intensity of physical training. Several factors such as age, sex, training history, recovery, sleep and nutrition, as well as environmental, psychological, and social factors can significantly affect training adaptations in soldiers (Kyröläinen et al. 2018). The adaptive effect of the training can differ depending on different training variables, like type of exercise (strength, endurance), volume (repetitions, duration, distance), and work-rest-ratio (short, long). In addition, excessive training load combined with these external stress factors can lead to compromised training adaptations or overreaching or even overtraining in addition to increased musculoskeletal injury rates (Knapik et al. 2001; Rosendal et al. 2002; Tanskanen et al. 2011). All this should be carefully considered when trying to plan and implement optimal physical training programs for soldiers.

2.1.1 Physical activity in tactical occupations and during military training

Any bodily movement produced by skeletal muscles that requires energy expenditure is defined as a physical activity (PA) (Bouchard et al. 1994). PA can be measured subjectively by self-report questionnaires or diaries (Martins et al. 2013; Sharp et al. 2008) and by objective measures such as accelerometers and pedometers (Aittasalo et al. 2015; Knapik et al. 2007; Wyss et al. 2010; Vähä-Ypyä et al. 2015). Objectively measured PA can be examined either by counting the steps taken per day or by quantifying the activity as a level of metabolic equivalent (MET). In the studies with pedometers, it is impossible to distinguish whether the steps are taken by walking or running. The accelerometers and mathematical algorithms make it possible to discern running versus walking steps as well as enable calculation of the level of activity in MET (Vähä-Ypyä et al. 2015). According to Tudor-Locke et al. (2008) over 10000 steps per day can be classified as a physically active day. MET is defined as the ratio of the metabolic rate during PA to the resting metabolic rate (given value of 1.0). One MET is equivalent to the oxygen consumption of 3.5 ml/kg/min, which corresponds to sitting quietly (Ainsworth et al. 2000, Ainsworth et al. 2011). Physical activity can be divided into sedentary (SED) (< 1.5 MET), light (LPA) (1.5–2.99 MET), moderate (MPA) (3.0–5.99 MET) and vigorous (VPA) (≥ 6.0) (Pate et al. 1995; Vähä-Ypyä et al. 2015). Among tactical athletes, Vincent et al. (2016) and Chapel et al. (2016) have reported physical activity in MET values for firefighters and Redmond et al. (2013) and Wyss et al. (2012) for soldiers. Common military training mostly involves medium (3–4 METs) to heavy (5–6 METs) workload PA (Ainsworth et al. 2000; Ainsworth et al. 2011). Very heavy (METs over 7) work may be performed during strenuous field marches with heavy load or active combat exercises (Kyröläinen et al. 2008; Nindl et al. 2006).

When studying the physiological changes induced by military field training (MFT), examination into the amount of physical activity is necessary to be able to compare the level of physical stress to non-field training weeks. Knapik et al. (2007) have found that during the US Army Basic Combat Training (US Army BCT), soldiers performed an average of 16311 ± 5826 steps per day and the highest daily average (22372 ± 12517 steps per day) was found during MFT exercise. In a study conducted among German soldiers, Schulze et al. (2015, 2016) observed that only the junior enlisted soldiers reached over 10000 steps in a day, while non-commissioned officers and officers did not reach that level. Further, the average step count during military training in Norwegian Home Guard –troops was unchanged when compared to step counts during normal civilian life (Aandstad et al. 2016). Rintamäki et al. (2012) found that during a peacekeeping operation in Chad, soldiers took an average of only 5797 steps during their 12-hour working shift.

When looking at the level of activity in METs, Wyss et al. (2012) found that Swiss conscripts had 7:33:00 to 8:40:00 h:min:s of LPA, 3:45:00 to 5:46:00 h:min:s of MPA and 0:05:00 to 0:16:00 h:min:s of VPA per training day. During US Army BCT the recruits had on average 7:25:30 hours of sedentary activity, 2:20:30 hours of light activity (> 3.0 MET), 1:32:00 of moderate activity (3.0–6.0 MET) and 0:38:00 hours of vigorous (> 6.0 MET) activity during a training day (Simpson et al. 2013). Aandstad et al. (2016) observed that the average VPA during military training was significantly lower than during civilian life, but there was more MPA during military training compared to civilian life in Norwegian Home Guard - troops. In firefighters, Vincent et al. (2016) have found that firefighters had an average of 7:33:00 hours of LPA, 2:36:00 hours of MPA and 0:00:19 hours of VPA. Chappel et al. (2016) had similar findings with 7:10:00 hours of LPA, 2:32:00 hours of MPA and 0:00:20 hours of VPA.

2.1.2 Changes in physical performance during military training

Optimizing performance in military environments is often challenging due to external stress factors, such as prolonged physical activity (often while carrying loads), negative energy and fluid balance, sustained readiness, and sleep deprivation (Booth et al. 2006; Henning et al. 2011; Tharion et al. 2005). These stressors have been shown to cause disruptions in hormonal balance (Alemany et al. 2008; Chester et al. 2013; Kyröläinen et al. 2008; Tyyskä et al. 2010), leading to reduced physical and cognitive performance (Nindl et al. 2002; Nindl et al. 2007; Margolis et al. 2013; Richmond et al. 2014; Tharion et al. 2005), extended recovery times (Henning et al. 2014) and increased susceptibility to infections (Diment et al. 2012). Military training and work can be classified as low-intensity, high-volume endurance-focused physical activity. If appropriate recovery is not taken into account when designing physical training routines combined with daily military training, this may lead to overreaching and in the worst scenario into the overtraining syndrome (Tanskanen et al. 2011; Vrijkotte et al. 2019). All these stress factors should be considered when designing an optimal training periodization in the military environment (Jones et al. 2017).

Table 1 presents studies done in the past investigating different lengths of military training. Short-time (21 day or less) military field training has been found to influence soldiers' physical performance by decreasing cardiorespiratory endurance (Guezennec et al. 1994), muscle endurance (Rintamäki et al. 2012), and the ability to produce power in the lower body (Chester et al. 2013; Nindl et al. 2002). Various studies have indicated up to 10% decreases in upper body strength as well as in lower body strength (from 15% to 20%). In addition, a decrease in power of the lower extremities in combination with a decrease in aerobic fitness has been reported after a military field exercise (Nindl et al. 2002; Nindl et al. 2007; Henning et al. 2011; O´Leary et al. 2020; Vaara et al. 2015). For example, Chester et al. (2013) reported a 10% decrease in lower-body force development following a 14-day military survival training. In addition, Nindl et al. (2002)

found decreases of 9% and 15% in mean jump power and total work during a 72-hour military field exercise consisting of prolonged physical activity and energy deficit. Hamarsland et al. (2018) studied a group of Norwegian Special Forces during a strenuous 7-day selection course and found a 28% decrease in counter movement jump height, 20% decrease in lower-body strength, and 10% decrease in upper-body strength. Upper-body strength recovered over a one-week recovery period, but lower-body strength and power did not recover within the two weeks recovery period.

Vaara et al. (2015) observed a reduction in maximal strength of the lower extremities, but not in the upper extremities after a 5-day paratrooper field exercise. Strenuous military training periods lasting eight or more weeks have been shown to cause drastic declines (up to 20%) in maximal strength and the ability to produce power in soldiers (Nindl et al. 2007; Richmond et al. 2014; Sporis et al. 2012). A decline in physical fitness during MFT was associated with decreases in various components of body composition (Henning et al. 2011; Montain et al. 2003; Nindl et al. 2007; Vaara et al. 2015). Declines in muscle mass, fat mass, and fat free mass have been found (Alemany et al. 2008; Chester et al. 2013; Guezennec et al. 1994, Kyröläinen et al. 2008; Nindl et al. 2002; Rintamäki et al. 2012). During long international operations (Lester et al. 2010; Sharp et al. 2008) declines in aerobic performance have been observed, although muscular strength and power seem to be maintained or even developed during operations.

TABLE 1 Studies investigating the changes in aerobic performance, muscle strength or body composition during military training.

Study	N, Coun-	Study Design	Summary of Findings
Guezennec et al. 1994	27, FRA	5-day military combat course	Power ↓ 14%, Aerobic endurance ↓ 8%
Nindl et al. 2002	10, USA	72-hour military operational stress	Squat Jump Power ↓ 9%, Wall building ↓ 25%, Fat free mass ↓ 2%, Fat mass ↓ 7%
Nindl et al. 2007	50, USA	8-week intensive U.S. Army Ranger train-	Power ↓ 21%, Maximal strength ↓ 20%, Body mass ↓ 13%, Fat free mass ↓ 6%
Alemany et al. 2008	34, USA	8-day strenuous military field training	Body mass ↓ 4%, Fat free mass ↓ 2%, Fat mass ↓ 10%
Santtila et al. 2008	72, FIN	8-week Basic training period	Body fat ↓, Lower body strength ↑ 9–13%, VO2 max ↑ 9–13%
Sharp et al. 2008	110, USA	9-month operation in Afghanistan	VO_2 Max ↓ 5%, Upper body power ↓ 5%, Lower body power ↔, Body mass ↓ 2%, Fat free mass ↓ 4%, Fat mass ↑ 8%
Kyröläinen et al. 2008	7, FIN	20-day military field training	Body mass ↓ 4,2 %
Lester et al. 2010	73, USA	13-month operation in Afghanistan / Iraq	Upper and lower body strength ↑ (7–8%), Lower body power ↔, Upper body power ↑ 9%, Fat free mass ↑ 3%, Aerobic fitness ↓, 13%, Fat mass ↑ 9%
Crawford et al. 2011	99, USA	Influence of body fat to soldiers physical performance	Less fat, Aerobic and anaerobic endurance ↑, Strength ↑
Diment et al. 2012	30, UK	8-week arduous military training program	Body mass ↓ 6%, Fat free mass ↓ 3%, Fat mass ↓ 4%
Rintamäki et al. 2012	20, FIN	Influence of heat to soldiers physical performance	Body mass ↓ 4%, Fat mass ↔, Sit-ups ↑ 11%, Push-ups ↔, Repeated squat ↔, Leg extension ↑ 8%, Lower body power 27%
Sporis et al. 2012	25, CRO	Effects of Special operations 9-week basic training program	Body mass ↓ 2%, Upper Body Strength ↓ 7%, Lower body power ↓ 4%, Aerobic endurance ↓ 20%
Tanskanen et al. 2012	26, FIN	8-day winter military field training	Lower body power ↔, Hand grip strength ↓ 4%, 3 km loaded run ↓ 6%
Mikkola et al. 2012	945, FIN	Changes of aerobic endurance and body composition during conscript service	Aerobic endurance ↑ 7%
Chester et al. 2013	14, AUS	14-day military survival training	Body mass ↓ 8%, Lower body power ↓ 10%
Margolis et al. 2014	21, NOR	7-day winter military field training	Lower body power ↓ 9%
Richmond et al. 2014	40, UK	8-week tactics phase in military training	Body mass ↓ 6%, Fat free mass ↓ 1%, Fat mass ↓ 26%
Vaara et al. 2015	52, FIN	5-day military field training	Standing long jump ↓, Push-ups ↑, Sit-ups ↑
Hamarsland et al. 2018	15, NOR	Special Forces 7-day selection course	Body mass ↓ 7%, Lower body strength ↓ 20%, Upper body strength ↓ 9%, Lower body power ↓ 28%
Szivak et al. 2018	20, USA	14-day military survival training	Body mass ↓ 6,9%, Hand strength ↔, Lower body power ↔
Vikmoen et al. 2020	35, NOR (23 M, 12	6-day military field training	Body mass ↓ 8% (M), ↓ 4% (F) Lower body power; ↓ 19% (M), ↓ 19% (F) Upper body power; ↓ 10% (M), ↓ 14% (F)

2.1.3 Hormonal changes during military training

Military training and operations lead to changes in different hormonal biomarkers that modulate energy metabolism and tissue level adaptations, including muscle protein synthesis and breakdown. Measuring serum hormone concentrations is a useful tool to evaluate the effects of different training programs and physiological changes in soldiers. Previous military field exercise studies (Chester et al. 2013; Nindl et al. 2002; Nindl et al. 2007; Sporis et al. 2012) have shown that prolonged physical activity and negative energy balance, combined with sleep deprivation have a negative impact on the neuromuscular performance and hormonal balance of soldiers. Insulin-like growth factor – 1 (IGF-1) is a particularly important biomarker, as it has been demonstrated that the circulating levels of IGF-1 are positively associated with aerobic fitness (Nindl et al. 2011). Additional biomarkers (i.e., Cortisol (COR), Testosterone (TES), and Sex Hormone Binding Globulin (SHBG)) have also been shown to predict the rates and extent of physical performance changes. In addition to the ability of biomarkers to predict fitness measures, certain biomarkers or hormones that are sensitive to changes in homeostasis may serve as early indicators of stress or overreaching. (Kyröläinen et al. 2008; Nindl et al. 2003; Tanskanen et al. 2011). Previous studies have demonstrated that MFT including physical exertion combined with energy and sleep deprivation causes changes in several serum hormone concentrations (Alemany et al. 2008; Friedl et al. 2000; Kyröläinen et al. 2008; Nindl et al. 2007; Richmond et al. 2014). When looking at longer military training, Friedl et al. (2000) showed significant decreases in TES and IGF-1 concentrations following an 8-week military field training period with increases in SHBG and COR concentrations.

Testosterone (TES) is a lipid-based 19-carbon steroid hormone, which is produced in the Leydig cells of the testis and is considered to be an anabolic hormone that is principally responsible for the stimulation of protein synthesis in muscle and bone (Florini 1970; Linderman et al. 2020; Mauras et al. 1998). The production of TES is regulated by the hypothalamic-pituitary-gonadal axis. TES promotes muscle hypertrophy (Vingren et al. 2010) by stimulating myofibrillar protein synthesis (Mauras et al. 1998) and inhibiting protein degradation (Demling & Orgill 2000). TES levels undergo circadian variation with values being the highest in the morning. The total TES reference value in males is 10–38 nmol/l. Most of the TES in blood is bound by sex hormone binding globulin (SHBG) (Vingren et al. 2010). TES also stimulates the production of other anabolic hormones (Vingren et al. 2010). For example, TES has a synergistic effect on IGF-1 release in association with 22 kDa growth hormone (Mauras et al. 2003). TES has been reported to decrease during MFT by 24–49% (Alemany et al. 2008; Hamarsland et al. 2018; Kyröläinen et al. 2008; Nindl et al. 2006). Normally, the basal TES levels have been found to recover after a period of 2–4 days with adequate rest and nutrition (Salonen et al. 2019).

Sex hormone-binding globulin (SHBG) is a 90 kDa glycoprotein composed of two 373-amino-acid subunits and is primarily synthesized in the liver. SHBG binds to specific sex hormones, including TES and removes them from direct circulation within the blood stream (Wallace et al. 2013). The reference values for serum SHBG in males is 11–78 nmol/l. SHBG has also been reported to increase under energy restriction and during physical exertion (Alemany et al. 2008; Friedl et al. 2008; Henning et al. 2014). SHBG is also known to inhibit the function of TES and has been observed to increase during strenuous military field training (Alemany et al. 2008; Friedl et al. 2000; Kyröläinen et al. 2008; Nindl et al. 2002; Nindl et al. 2007; Tanskanen et al. 2011). Increased levels of SHBG and decreases in TES have also been reported to indicate insufficient recovery (Häkkinen et al. 1985b). The TES/SHBG –ratio has been used as a potential marker of overtraining. (Häkkinen et al. 1987; Kraemer et al. 2006)

IGF-1 is a liver derived 7.6 kDa polypeptide that has an essential role in stimulating protein synthesis and maintaining muscle mass (Jones & Clemmons 1995). IGF-1 has been shown to serve as a potential biomarker for health, fitness, and training status of soldiers (Nindl et al. 2017) during military training. Nindl et al. (2011) found that higher circulating IGF-1 values are associated with improved muscular endurance and cardiovascular health. During strenuous MFT, high physical strain combined with energy deficiencies have been shown to increase IGF-1 concentrations in the blood (Friedl et al. 2015; Nindl et al. 2002; Vaara et al. 2015). Rosendal et al. (2002) reported a significant decline in total IGF-1 values after 11 weeks of garrison training. There have also been decreases in IGF-1 values after MFT (Nindl 2009) and longer special force training (Friedl et al. 2000; Nindl et al., 2007). Intensive field training can lead to drastic declines in total TES and IGF-1 concentrations (Nindl et al. 2007).

Cortisol (COR) is released from the adrenal cortex in response to psychological and physical stress (Kraemer & Ratamess 2005). Cortisol secretion is influenced by the circadian rhythm, with its values being lowest at the end of the day and highest in the morning. An antagonist to TES, COR inhibits protein synthesis by interfering with the binding of TES to its androgen receptor and by blocking anabolic signalling through TES-independent mechanisms. Chronic stress has been reported to have a negative impact on cognitive function, and high levels of COR may suppress immune function and increase the risk of infections (Szivak et al. 2015). COR has widely been measured during MFT, and it has been shown to increase by 32–154% (Alemany et al. 2008; Friedl et al. 2000; Hamarsland et al. 2018; Kyröläinen et al. 2008; Nindl et al. 2002; Nindl et al. 2007; Tanskanen et al. 2011). The TES/COR – ratio has been shown to decrease after a week of overreaching endurance training (Adlercreutz et al. 1986) and at the end of a prolonged strength training period (Häkkinen et al. 1985a) as well as during an intensive high-volume strength training week in weightlifters (Häkkinen et al. 1988). Similar observations have been made in soldiers (Booth et al. 2006; Fortes et al. 2011). Previously the TES/COR – ratio has been used in conscripts to study military training load (Santtila et al. 2009) and chronic overtraining (Tanskanen et al. 2011) during military basic training.

Nindl et al. (2006) studied the effects of short term MFT on hormonal responses. The study showed that there was a 3% loss in body mass and 24 to 30 %

loss in free TES levels following MFT. Kyröläinen et al. (2008) found that COR levels are significantly increased (32%) while TES levels are reduced (27%) in the first few days of strenuous MFT. In addition, SHBG levels have been found to increase during basic military training (Tanskanen et al. 2011), and during heavy and strenuous MFT (Nindl et al. 2003). Pasiakos et al. (2019) studied the effects of exercise- and diet-induced energy deficit on body composition during a 28-day experiment on healthy men. The subjects were randomly divided into two groups: placebo and testosterone supplement groups. The results showed that the decrease in free TES levels and body mass was greater in the placebo group. The supplement group recovered to the baseline in a shorter time than the placebo group. As seen in Table 2, military training can lead to drastic changes in serum hormone concentrations. If this kind of stress continues for extended periods, it can lead to insufficient recovery and an inability to maintain optimal occupational readiness and performance. Szivak et al. (2015) have suggested that physically fit soldiers are more resilient to different operational stressors. Greater fitness enables quicker recovery from high military stress via improved sensitivity of the endocrine system (Szivak et al. 2018).

TABLE 2 Studies investigating the changes in serum hormone concentrations (TES, COR, SHBG, IGF-1) during the military training.

Study	N, Country	Study Design	Summary of Findings
Opstad 1992	11, NOR	5-day military field training	TES ↓, COR ↑
Friedl et al. 2000	97, USA	8-week US Army Ranger course	TES ↓ 86%, IGF-1 ↓ 57%, COR ↑ 60%
Gomez-Merino et al. 2002	26, FRA	3-week Combat training, followed by 5-day arduous military training	TES ↓ 35%, COR ↑ 2.7%
Nindl et al. 2003	12, USA	72-hour military operational field training	IGF-1 ↓ 32%, IGFBP-3 ↓ 23%
Nindl et al. 2006	10, USA	84 h physically strenuous exercise, including caloric restriction and sleep deprivation	IGF-1 ↓ 27%, TES ↓ 24%
Nindl et al. 2007	50, USA	8-week US Army Ranger course	TES ↓, IGF-1 ↓, COR ↑
Alemany et al. 2008	34, USA	8-day physically strenuous exercise, including caloric restriction and sleep deprivation	IGF-1 ↓ 50%, TES ↓ 49%, SHBG ↑ 66%
Kyröläinen et al. 2008	7, FIN	20-day prolonged reconnaissance exercise	TES ↓ 27% after 5 days, COR ↑ 32% after 5 days
Santtila et al. 2009	72, FIN	Basic military training period (8 weeks) divided into three training groups	TES ↑ 16–27% (all groups), COR ↑ 11% (only strength group)
Tyyskä et al. 2010	9, FIN	15-day military field training	TES/SHBG – ratio ↓ 28 % with low physical fitness
Tanskanen et al. 2011	57, FIN	Basic military training period (8 weeks)	SHBG ↑, IGF-1 ↓, COR ↓
Vaara et al. 2015	52, FIN	Parachute training period (11 weeks), including 5-day military field training	IGF-1 ↓ 28%
Hamarsland et al. 2018	15, NOR	Norwegian SOF selection course	TES ↑ 70%, COR ↑ 154%, IGF-1 ↓ 51%
Ojanen et al. 2018	49, FIN	21-day military field training	IGF-1 ↓ 22%
Szivak et al. 2018	20, USA	U.S. NAVY SERE – course	ADR + NORADR ↑
Salonen et al. 2019	20, FIN	7-day military field training	TES ↓ 56%, COR ↓ 32%, SHBG ↑ 28%

2.1.4 Effects of military field training on sleep, caloric intake, expenditure and shooting performance in soldiers

Strenuous MFT with extended periods of caloric deficit, lack of or disturbed sleep and high-energy expenditure causes changes to body composition of soldiers as seen in Table 3. A decline in body mass and, especially, in body fat mass has been observed (Johnson et al. 2018; Kyröläinen et al. 2008; Margolis et al. 2014; Tanskanen et al. 2012; Tassone et al. 2017). During longer military training with energy deficit, fat free mass has also been shown to decline in soldiers (Nindl et al. 2007; Richmond et al. 2014; Sporis et al. 2012). Longer military operations seem to lead to increases in body fat (Lester et al. 2010; Pihlainen et al. 2018; Sharp et al. 2008). Energy expenditure is high during strenuous MFT (6000–8000 kcal) (Hamasland et al 2018; Johnson et al. 2018; Kyröläinen et al. 2008; Margolis et al. 2014). The work of a soldier during MFT requires more energy than they consume from food. Friedl et al. (2000) found that during US Army Ranger training, soldiers lose 15% of body mass, 7% of fat free mass and 65% of their fat mass. Strenuous military training can lead to decreased body mass, not only through reductions in fat mass, but also through the loss of fat free mass. Therefore, it is important from a physiological point of view to have a sufficient recovery period following strenuous MFT before deployment.

Shooting is one of the most important occupational skills for a soldier; however, there is limited information regarding shooting performance and how it is affected by prolonged MFT. Previous studies have shown that shooting performance differs as a result of different physical loading intensities (Frykman et al. 2012; Jaworski et al. 2015; Swain et al. 2011; Tenan et al. 2017; Vickers & Williams 2007). Soldiers are required to move on the battlefield while simultaneously maximizing their shot accuracy in a state of elevated heart rate and fatigue (Frykman et al. 2012). Multiple factors affect the accuracy of shooting in soldiers. Anxiety has been shown to decrease the accuracy of shooting as well as negatively impact decision-making (Nibbeling & Oudejans 2014). Fatigue has also been indicated as a significant factor affecting marksmanship, especially after anaerobic physical strain (Frykman et al. 2012; Jaworski et al. 2015; Swain et al. 2011). In addition to anxiety and fatigue, sleep deprivation has a detrimental effect on shooting accuracy.

In earlier studies, soldiers' shooting performance has mainly been measured after different simulations of military work. These studies have shown that arduous anaerobic work can decrease shooting accuracy, but accuracy recovers quickly (Frykman et al. 2012). Evans et al. (2003) observed that a fatiguing upper body obstacle course significantly decreased shooting accuracy, but again, accuracy recovered quickly. Load carriage has also been shown to decrease shooting accuracy (Knapik et al. 1997), although it seems that there is no change before the carried load of 45% of body weight (Jaworski et al. 2015). In a study of Tenan et al. (2017), shooting performance was studied during a loaded march with live-fire shooting in the field. They found that load carriage and marching did not affect shooting accuracy; actually, the shooting improved with lighter loads.

TABLE 3 Studies investigating the impact of caloric and sleep deficit during the military training.

Study	N, Country	Study Design	Summary of Findings
Nindl et al. 2007	50, USA	8-week intensive U.S. Army Ranger training	Energy deficit => 1000–4000 kcal/day 20 % decrease in maximal strength and power
Kyröläinen et al. 2008	7, FIN	20-day prolonged reconnaissance exercise	Energy deficit => 4000 kcal/day; 1st week days; 450 kcal/day, 2nd week; 1000 kcal/day, 3rd week)
Tanskanen et al. 2012	26, FIN	8 day physically strenuous exercise with provided extra protein	No effects on physical activity or energy deficit
Margolis et al. 2014	21, NOR	7-day winter military field training, with 3-day ski march (54 km)	Energy expenditure higher during ski march (6851 vs 5480 kcal)
Richmond et al. 2014	40, USA	8 week physically intensive training	Body weight decreased 5 kg due to energy deficit
Tassone et al. 2017	Review	A systematic literature review of body weight and body composition changes during military training and deployment	Body weight and composition should be routinely monitored before and after field activities.
Johnson et al. 2018	29, USA	Energy expenditure and intake in a jungle and glacial environment in SOF soldiers	Energy intake higher in cold environment, energy deficit from 1600–2400 kcal/day, energy
Vaara et al. 2018	20, FIN	60-hour sleep deprivation effects on physical performance	Maximal neuromuscular and aerobic performances were unaffected. Submaximal aerobic seems to be attenuated after sleep deprivation.

2.2 Effects of strength training on physical fitness in soldiers

2.2.1 Acute responses and chronic adaptations to strength training in soldiers

Heavy resistance training typically results in acute decreases in maximal force production, neural activation, and in the force-time curve of the loaded muscles (Häkkinen 1994a; Häkkinen & Pakarinen 1993). The acute responses and chronic adaptations that occur during and after a strength training session are highly dependent upon specific training variables, such as volume, intensity, and recovery between the sets. Hypertrophic type of strength training can produce up to 40 % reduction in force production (Ahtiainen et al. 2003). Generating greater force requires higher activation of motor units to fulfil the work demand. When systematically training to increase muscle strength, much of the strength improvement is due to adaptations within the nervous system, especially in the early weeks of training (Aagaard 2003; Häkkinen & Komi 1983; Moritani & DeVries 1979). According to Henneman´s (1957) size principle theory, during low or submaximal exercise intensity, smaller type I (aerobic) muscle fibres are primarily activated. Closer to maximal effort, bigger type II muscle fibres become activated to accomplish the higher demand of force production. Prolonged strength training leads to changes in neurological and morphological factors, such as changes in voluntary motor unit activation and muscle fibre size, which subsequently result in increased muscle size and strength. Training volume, type and intensity also determine the magnitude of hypertrophy and changes to muscle strength (Kraemer et al. 2012).

Muscular endurance can be improved by training with relatively low intensity (< 60% of 1RM) and high volume of repetitions (> 20). Higher volume and intensity strength training e.g., hypertrophic type (60–80% of 1RM, 10 to 15 reps, and short recovery ≤ 1.5 min), has been shown to improve muscular strength by substantially increasing muscle size and mass. Higher intensity and lower volume (> 80 % of 1RM) trains maximal strength, while explosive strength is trained with medium loads (40–60% 1RM, 3–6 reps, and 2–5 min recovery) with fast repetitions. Neural adaptations (e.g., increased activation of agonist muscles) primarily underlie changes to both maximal and explosive strength with each involving changes to various levels of the neuromuscular system (Häkkinen 1994b; Häkkinen et al. 1998). Decrements in maximal force production observed immediately after submaximal and power protocols, seem to recover during the first hour following the exercise (McCaulley et al. 2009). When looking at heavy hypertrophic and maximal type of training, longer recovery times of 48–72 hours can be required (Ahtiainen et al. 2004; Häkkinen 1994a). Hypertrophic type of strength training creates large acute increases to cortisol, growth hormone, testosterone, and IGF-1 concentrations in the body. Studies have shown that during the first 6–8 weeks of strength training, most improvement comes from adaptations in neuromuscular performance e.g., enhancement of the motor units firing patterns (Häkkinen & Komi 1983; Häkkinen et al. 1998; Moritani & DeVries 1978).

Within 8–12 weeks, mechanical adaptations, such as enhanced cross-sectional area of the strength-trained muscles, can be observed (Häkkinen et al. 1985a; MacDougall et al. 1980). The amount of neural versus morphological adaptations is dependent on both the training duration and mode. (Schoenfeld 2010). Hypertrophic strength training typically induces muscle growth, while explosive and maximal strength training provoke neural adaptations (Kraemer & Ratamess 2005).

Mechanisms contributing to training adaptations and muscle hypertrophy include mechanical factors and metabolic factors. The loading of muscle can be described as mechanical tension, and it is proposed to interrupt skeletal muscle structures and to lead to cellular responses via stimulation of anabolic (mTOR) and catabolic pathways (Duchateau et al. 2021).

Prolonged MFT has been shown to lead to a decrease in maximal strength and power (Nindl et al. 2002; Nindl et al. 2007). The military environment creates a special platform for strength development because endurance training is always integrated into soldiers' training programs (Friedl et al. 2015). Load carriage studies have shown that added strength training can increase soldiers' capability to carry load (Knapik et al. 2004).

Santtila et al. (2008) studied conscripts and found that basic military training leads to increases in physical performance including both endurance and strength capability. Similar results have also been reported during U.S. Army Basic Training (Hendrickson et al. 2010; Knapik et al. 2001). Increases in strength and power have also been reported in previously trained soldiers with different strength training programs (Abt et al. 2016; Lester et al. 2014; Solberg et al. 2015). In a study by Vantarakis et al. (2017), an 8-week strength training intervention was compared to regular training in Naval Cadets. The intervention group performed daily strength training sessions, while the training varied in the regular training group (e.g., team-sports, swimming, body-weight training). The intervention group improved their performance in several strength tests (e.g., 1RM bench press, 1RM squat) and occupational obstacle course significantly more than the regular training group.

2.2.2 Periodization of strength training

Periodized strength training programs are needed to maximize training adaptations. Periodization of training means planning of training sessions and breaking the training into periods with specific training goals (Bomba & Buzzichelli 2019, p. 91). A training plan can be divided into micro- and mesocycles. A microcycle is typically a 7-to-10-day training phase, while a mesocycle normally consists of 4–6 microcycles. For example, a yearly training plan can consist of 3 or 4 mesocycles (e.g., preparatory, competitive, and transition). Periodization models include linear, non-linear, and block periodization. Linear periodization is most common, where the intensity of training (load) is linearly increased. In non-linear periodization, load is also progressively increased, but the variation in volume and intensity is decided by the training phase (mesocycle). In block periodization, variation is present across the training period, with focus on varying the training modes and intensities within microcycles (Haff 2016, pp. 583–604).

Nowadays, military occupations require more physical fitness than in the past (Friedl et al. 2015; Knapik et al. 2004). In recruits or conscripts, military training involves a high amount of physical activity, which can be a new experience for many. Therefore, it is important to start physical training immediately during basic training to ensure that all recruits are able to improve their physical performance in the beginning of their service and build a solid platform to build upon with additional physical training after the basic training period (Hofstetter et al. 2012; Santtila et al. 2015; Sporis et al. 2014). After basic training, strength training should be employed with the aim of reaching the occupational standards before deployment. While deployed, the goal is to maintain strength capacity; and post-deployment can be seen as a transition period, which aims for recovery and injury rehabilitation. (Billing et al. 2017).

Different periodization models have been previously used in the military context. Santtila et al. (2010) used a whole-body linear strength training periodization during an 8-week basic training period. Increased performance was observed in a loaded combat run test. Kraemer et al. (2004) used a non-linear 12-week periodization model to enhance muscle hypertrophy and strength. Both sit-ups and push-ups improved significantly during the study, but loaded running performance did not. Solberg et al. (2015) studied the differences between a 6-month linear and a 6-month non-linear training program and found that both programs improved strength and power variables, but the linear periodization tended to be more difficult to follow within the military context. Abt et al. (2016) compared a 12-week non-linear periodization to block periodization and found that both programs improved upper and lower muscular power along with upper body muscular endurance, although only the block periodization showed significant improvements in total body strength.

2.3 Effects of endurance training on physical fitness in soldiers

2.3.1 Acute responses and chronic adaptations to endurance training in soldiers

Aerobic capacity is as important as strength in soldiers. Endurance training can be divided into two categories: long duration low-to-moderate intensity (50–70% VO_2max) basic training and high-intensity interval type of training (> 70% VO_2max) (Bomba & Buzzichelli 2019, pp. 265–267). Normally endurance training has been described as submaximal muscular work, performed over a prolonged period of time against a relatively low load (Hughes et al. 2017). In the past, endurance training has involved mostly long duration, low to moderate intensity training, but in recent years high-intensity interval training (HIIT) has become a more popular way to improve endurance. HIIT can be a time-effective training option compared to traditional endurance training, leading to similar or greater changes in cardiovascular and endurance performance (MacInnis & Gibala et al. 2017).

Acute responses to endurance exercise include increases in heart rate, oxygen consumption, stroke volume, blood flow, cardiac output, blood pressure, ventilation, and breathing rate. (Alvar, Sell & Deuster 2017, pp. 17-20). Consistent endurance training leads to central (e.g., increased VO_2max) and peripheral (e.g., increased capillary and mitochondrial density) adaptations, which combined lead to improved oxygen transportation (Helgerud et al. 2007; Hughes et al. 2017). Likewise, with strength training, muscle fibres are activated according to the size principle during endurance training. Low-intensity endurance training activates type I fibres, while higher intensity endurance exercise requires the activation of type II muscle fibres (Bomba and Buzzichelli 2019, p. 276). Endurance exercise has been shown to lead to an acute decrease in strength, typically by 10–30 % (Millet et al. 2009). It must be remembered that the magnitude of strength decline depends on the duration, intensity, and type of endurance loading. In a study with triathletes, Cohen et al. (2010) found that the rate of force development and maximal strength remained unaffected during a prolonged training period. Mikkola et al. (2012) observed a small but statistically significant increase in muscle cross-sectional area following endurance training in physically active subjects. On the contrary, Kraemer et al. (1995) found significant decreases in muscle fibre size following prolonged high-intensity endurance training. The ability of prolonged endurance training to develop muscle size may not be desirable for endurance athletes, but might be beneficial for soldiers.

2.3.2 Periodization of endurance training

Typical daily military training can be classified as low intensity, long duration endurance training (Aandstad et al. 2016; Wyss et al. 2012). In addition, the overall daily volume of low-to-moderate intensity work is high during normal military training (Jurvelin et al. 2020; Wyss et al. 2012). This may explain why added endurance training has not been observed to produce positive adaptations during military basic training (Santtila et al. 2009). Contrastingly, increased intensity and reduced volume of endurance training during military training have been shown to induce greater adaptations in endurance performance when compared to traditional low-to-moderate intensity training (Kilen et al. 2015).

Low-intensity exercise endurance (LIEE) is important in improving oxidative or aerobic metabolism. Conversely, LIEE can reduce the ability of soldiers to produce force in the high-velocity region of the force-velocity curve (Häkkinen & Myllylä, 1990). LIEE can also interfere with the ability to develop explosive power (Elliot et al. 2009). High-intensity exercise endurance (HIEE), on the other hand, has been shown to maintain type II muscle fibre content and does not seem to reduce maximal strength or power development (Elliot et al. 2009). This is important to take into account when designing training programs for soldiers. As the amount of LIEE is already high during daily occupational duties for soldiers, it may be that training HIEE rather than LIEE will better target and improve the aspects of endurance relevant for improving physical and military performance.

2.4 Effects of combined strength and endurance training on physical fitness in soldiers

2.4.1 Acute responses and chronic adaptations to combined training in soldiers

During concurrent endurance and strength training, the order in which each type of training is performed can vary. If endurance training is performed immediately prior to strength training, it can diminish the quality, volume, and intensity of strength training due to residual fatigue. This residual fatigue can compromise the ability of the muscles to generate sufficient muscular tension and thus reduce the positive adaptive response of the strength training session (Coffey & Hawley 2017). In the same way, if the strength training session is performed immediately prior to the endurance training session, the strength training-induced fatigue can compromise and reduce the positive adaptive responses of the endurance training session. (Taipale et al. 2015). In both cases the exercise modality, intensity, and volume of the training session influences the outcome and the extent of any interference effect (Coffey & Hawley 2017).

The military environment creates a special platform for strength development, because endurance training is always integrated into soldiers training programs. It has been shown that high (> 3 times/week) endurance training frequency, especially with high training volumes, may have a negative influence on strength performance outcomes during concurrent training (Coffey & Hawley 2017; Hickson 1980; Wilson et al. 2012). Daily military training may also have a similar impact on the development of different physical characteristics. However, when training frequency is reduced to 2–3 strength and 2–3 endurance-training sessions per week, no interference in maximal strength development has been observed (Häkkinen et al. 2003; Wilson et al. 2012). The explanation for this interference effect has been explained by both acute and chronic hypotheses. In his pioneer study, Hickson (1980) proposed that the interference originates from the inability of the muscles to adapt to both endurance and strength training simultaneously. Residual fatigue from the first exercise is thought to affect the quality of the second exercise, and in this way compromise the long-term adaptations (Graig et al. 2012). Therefore, it appears that the recovery between strength and endurance training sessions is the most important factor for optimal strength and endurance adaptations to occur. Although 4–6 concurrent training sessions per week seems to be optimal to prevent interference, research suggests that adaptations in explosive force production may be more sensitive to interference than hypertrophic or maximal strength adaptations, even in low frequency combined training (Häkkinen et al. 2003; Mikkola et al. 2012; Wilson et al. 2012).

2.4.2 Periodization and interference effect

It appears that concurrent resistance and aerobic training is the optimal way to reduce musculoskeletal injury risk during military service and to meet the physical and occupational demands of daily military tasks (Burley et al. 2020; Kyröläinen et al. 2018; Vaara et al. 2021). Major military occupational tasks, like load carriage, casualty evacuation, and manual material handling, can benefit from the adaptations induced by periodized combined strength and endurance training (Burley et al. 2020; Heilbronn et al. 2020; Knapik et al. 2012). It must be remembered that recruits undergo many physical activities outside actual physical training. These activities mostly consist of high amounts of low-intensity aerobic work (Jurvelin et al. 2020), which may interfere with power and strength development and compromise occupational task development. When planning physical training for active-duty soldiers, it is important to note that new recruits or previously untrained soldiers may reap similar or greater benefits from concurrent training when compared to training each mode separately; however, soldiers with longer training experience are more prone to the interference effect (Coffey & Hawley 2017).

2.5 Effects of physical training on serum hormonal concentrations during military training

2.5.1 Hormonal responses and adaptations to strength training

In earlier studies, both endurance and strength training have been seen as powerful stimuli for acute and chronic hormonal adaptations, but the magnitude of the acute hormonal responses depend on the exercise mode, intensity and volume (Hackney et al. 2012; Häkkinen et al. 1988; Kraemer & Ratamess 2005). Short intensity endurance exercise may lead to acute elevations in both anabolic and catabolic hormone concentrations (Hackney et al. 2012). If the endurance exercise is prolonged and physically demanding, it may lead to decreases in TES and increases in COR (Kuoppasalmi et al. 1980). A single strength training session as well as continued strength training has been shown to affect the amounts of circulating hormones in the blood (Kraemer & Ratamess 2005). Total TES concentration has been shown to acutely increase after resistance exercise in men (Hakkinen & Pakarinen 1993; Kraemer & Ratamess 2005). Exercises involving heavy loads and short rest periods may result in increases in TES and COR concentrations (Kraemer et al. 1990). On the contrary, maximal and explosive strength training with long rest periods may not trigger increases in hormone concentrations (Kraemer et al. 1990; Häkkinen & Pakarinen 1993). Tremblay et al. (2004) reported that the acute elevation in TES after a strength-training session was greater in strength-trained than in endurance trained men. This could suggest that strength training has beneficial periodical (Häkkinen et al. 1985a; Häkkinen et al. 1987; Häkkinen et al. 1988) adaptations in TES as observed in strength-trained athletes (Häkkinen et al. 1987; Häkkinen et al. 1988). In addition, exercises such as Olympic lifts, squats or deadlifts, can cause greater elevations in TES concentrations compared to exercises involving smaller muscle groups (Kraemer & Ratamess 2005). COR concentrations have been shown to also increase acutely, especially during heavy strength loading, but no consistent pattern has been found with long-term training stress (Kraemer & Ratamess 2005). Resting IGF-1 concentration has been shown to be higher in resistance-trained than untrained men. It appears that the volume and training intensity are important factors for chronic IGF-1 adaptations (Kraemer & Ratamess 2005). An 8-week military strength training program resulted in an initial increase in IGF-1 concentration, but these values then decreased back to existing pre-values after training, and consequently no increase between the PRE and POST values were observed (Nindl et al. 2017). Similar findings have been observed in strength-trained athletes following 14 weeks of resistance training, as the training triggered a significant acute increase in TES concentration, but after 7 weeks of reduced training, the TES concentration decreased to baseline (Ahtiainen et al. 2003). These findings show that physical training can alter serum hormone concentrations acutely and even chronically, which is relevant when designing prolonged training programs.

2.5.2 Hormonal responses and adaptations to endurance training

The scale of acute responses to endurance exercise depends on the exercise type, intensity, and duration (Kuoppasalmi et al. 1980; Trembley et al. 2005; Vuorimaa et al. 2008). Short duration intensive anaerobic exercise can create greater acute TES and COR responses when compared to low-intensity training (Hackney et al. 2012, Kuoppasalmi et al. 1980; Van Bruggen et al. 2011). On the contrary, long-duration and physically demanding endurance training can increase TES and decrease COR concentrations (Kuoppasalmi et al. 1980). Endurance training causes basal testicular testosterone production to decline compared to untrained subjects (Hackney 1996). Prolonged high endurance training workload has been shown to lead to decreased basal TES concentrations in men (Hackney & Lane 2018). During prolonged endurance exercise, variable COR responses have been observed (Viru 1992). Viru and Viru (2004) reported that post-exercise increases in COR concentrations are essential for the synthesis of new amino acids.

SHBG has been shown to increase after endurance training both in non-trained (Zmuda et al. 1996), professional athletes (Popovic et al. 2019), and after a strenuous or prolonged military training (Drain et al. 2017; Tanskanen et al. 2011). On the contrary, IGF-1 has been shown to decline during traditional basic military physical training (Drain et al. 2017).

2.5.3 Hormonal responses and adaptations to combined training

Concurrent strength and endurance training has been reported to increase total and free testosterone concentrations to similar magnitudes as strength training alone (Shakeri et al 2012). Strength training and concurrent high intensity endurance training have also been reported to produce higher increases in cortisol and testosterone concentrations after a 12-week training period compared to baseline values (Kraemer et al. 1995). However, diurnal rhythms in testosterone and cortisol have remained statistically unaltered during combined strength and endurance training and are independent of the training order or time of day (Küüsmaa et al. 2016). However, these results indicate that combined strength and endurance training in the evening may lead to larger gains in muscle mass, while the E + S training order might be more beneficial for endurance performance development. In addition, training order and time seem to influence the magnitude of adaptations only when the training period exceeded 12 weeks. However, the exact responses of anabolic and catabolic hormone concentrations to combined training are not perfectly clear (Jones et al. 2017). It appears that the hormonal responses to concurrent training depend on the training background of the subjects and the combined training protocol (Cadore et al. 2012; Schumann et al. 2014). In addition, the anabolic environment is optimized when endurance exercise precedes strength exercise (Cadore et al. 2012; Rosa et al. 2015).

3 PURPOSE OF THE THESIS

It is well known that both physically demanding training and different occupational tasks make physical performance challenging for soldiers (Friedl et al. 2015). However, it remains unclear what kind of physical training (traditional military physical training, strength training or task-specific physical training) is the most effective for improving occupational performance in soldiers.

The present PhD thesis consisted of two studies, and the purpose of the present thesis was twofold:

Study 1 investigated the effects of a 21-day military field training (MFT) on the physiological responses in soldiers and examined the changes in muscle strength, power and endurance during and after prolonged MFT. The specific aims of the two original papers were:

1. To investigate changes in physical activity and neuromuscular performance among male Finnish Army conscripts during a 21-day MFT and to evaluate their recovery after MFT. The study also aimed to distinguish whether there were any associations between the above-mentioned variables. Additionally, it was assessed if four days of recovery at the end of the prolonged combat training period was sufficient to return all of the measured variables to the baseline level.

2. To examine the changes in body composition, upper and lower body strength, serum hormone (TES, COR, SHBG, IGF-1) concentrations and shooting accuracy during a prolonged MFT.

Hypothesis:
The primary hypothesis of the study was that the MFT would lead to a reduction in all measured variables (strength, power, endurance, and shooting performance). This study should provide better understanding of the associations between physical performance in soldiers and shooting capability during MFT.

Study 2 aimed to examine the influences of different types of physical training on physical performance in soldiers during a 12-week intervention study. The specific aims of these two original papers were:

3. To investigate the effects of two different training programs on strength and power performance and serum hormone concentrations in conscripts during a 12-week training program following the basic training period.

4. To determine which physical abilities are important for soldiers during a repeated simulated military task course and which type of training (task specific, strength, or traditional military fitness training) would be most useful and contribute to gains in these abilities during a specialized military training period.

Hypothesis:
It was hypothesized that all training types will improve performance in the simulated military task, but the task-specific training will improve performance beyond that of strength training. Further, it was theorized that both task-specific and strength training would improve strength and power performance more than normal military physical training.

4 METHODS

4.1 Subjects

In study 1, sixty-one Finnish Army male conscripts, who were conducting their mandatory military service and had completed two-thirds of the service time, volunteered as subjects to this study. During the 21-d field-training period, twelve (12) individuals dropped out mainly due to lack of motivation to participate in the study. Therefore, forty-nine (49) subjects completed the entire study. The subjects in study 1 were 19–22 year-old male conscripts. Their mean (± SD) age was 20 ± 1 years, height of 179 ± 6 cm, body mass 73.5 ± 8.7 kg and body mass index 23.0 ± 2.7 kg/m² (Table 4).

Study 2 was carried out with 104 male conscripts, who were also conducting their mandatory military service and had completed their basic training period (8 weeks) successfully and volunteered as participants for the second study. They were divided by their platoon into three training groups from 33–38 participants each, but only fifty-one (n = 51) of the total number of subjects completed all the measurements and training sessions during the 12-week study period leaving the following number of participants who were included in the study as follows: soldier task specific training group (TSG) (n = 19), strength training group (STG) (n = 20), and control group (CON) (n = 12) (paper III) and TSG (n = 17), STG (n = 15), CON (n = 10) for paper IV. Reasons for the missed measurements were overlap with the military training schedule and health-related problems such as flu or some musculoskeletal injury that prevented some participants to either attend the MID or POST testing sessions or to attend all the training sessions. The participants were 18–22 years old male conscripts. Their mean (± SD) age was 20 ± 1 years, height 180 ± 6 cm, body mass 72.4 ± 8.8 kg and body mass index 22.3 ± 2.2 kg/m² (Table 4).

Both studies were conducted according to the provisions of the Declaration of Helsinki and the ethical approval was granted by the Ethical Committee of the

University of Jyväskylä. The studies were also approved by the Finnish Defence Forces. All the conscripts were informed of the experimental design, and the benefits and possible risks that could be associated with the study prior to signing an informed consent document to participate in the study. The subjects were informed that they could cancel their participation at any stage if they wanted without any consequences.

TABLE 4 Subjects basal anthropometric characteristics (mean ± SD) in different papers.

Paper	Group	N	Age (yrs.)	Body mass (kg)	Body height (cm)	Body mass index (kg/m²)
I + II		49	20 ± 1	73.5 ± 8.7	179 ± 6	23.0 ± 2.7
III	TSG	19	20 ± 1	74.6 ± 10.4	180 ± 7	23.0 ± 2.2
	STG	20	20 ± 1	72.3 ± 7.5	182 ± 6	22.0 ± 1.7
	CON	12	20 ± 1	70.3 ± 10.2	180 ± 6	22.4 ± 2.9
IV	TSG	17	20 ± 1	73.2 ± 9.8	180 ± 7	22.7 ± 2.2
	STG	15	20 ± 1	73.8 ± 7.8	183 ± 6	22.1 ± 1.7
	CON	10	20 ± 1	71.1 ± 11.0	177 ± 4	22.7 ± 3.7

4.2 Experimental design

The present thesis consisted of two separate studies. Study 1 examined the cardiovascular and neuromuscular performance changes of conscripts including analysis of serum hormonal concentrations during a 21-day military field training period (original papers I, II). In Study 2, a 12-week training period was implemented after the basic training. Body composition, serum hormone concentrations, cardiovascular, neuromuscular, task specific and shooting performance were measured three times during the study period (original papers III, IV).

Study 1 consisted of different phases. A week before MFT, all the subjects were tested for their baseline values (PRE). The same tests were also performed on day 12 of MFT (MID), at the end of MFT (POST) and after a recovery period of four days (RECO). Body composition, serum hormone concentrations, neuromuscular, cardiovascular, and shooting performance were recorded during the measurement days (Figure 1).

The PRE-measurement week was a normal training week for the study participants. Their duties included lectures in the classroom, rifle maintenance and preparation for MFT. The entire 21-day MFT period, which was divided into three phases, was performed in field conditions. During the first phase (ST), the subjects performed combat drills and live-fire shooting exercises. The goal for each conscript was to improve their combat and shooting skills and advance their weapon handling abilities. In this phase, the aim was not to physically exhaust the conscripts but rather to ensure that each of them maintained a high level of performance by ensuring that they had an appropriate amount of rest and sleep. The normal training day started at 07:00 hours and ended no later than 19:00 hours.

In the second phase (MFT), they practiced moving from their base to their attacking positions for the last phase. The tasks performed included reconnaissance, combat manoeuvres, patrolling and tactical road marches. In the last phase (MFT), they executed the combat mission as a part of a larger military exercise. The tasks were the same as in the second phase. After the prolonged MFT, the subjects had four days of recovery, two at home and two at the garrison before the final study measurements were taken.

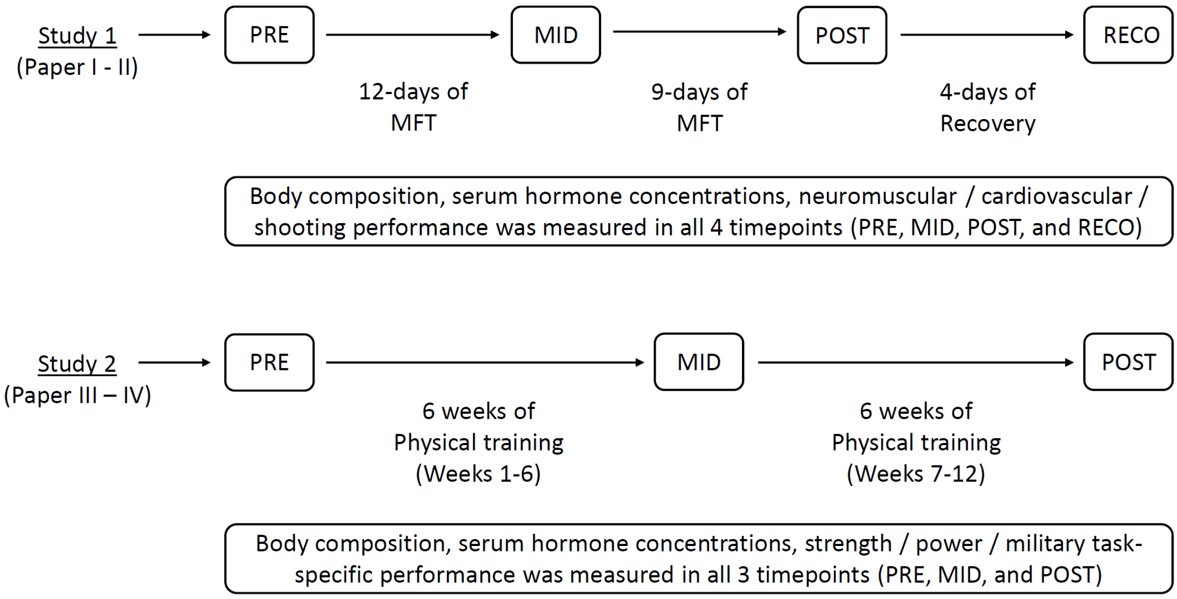

FIGURE 1 Experimental design of study 1 (21-d military field training) and study 2 (12-week training intervention).

In study 2 (Figure 1), body composition was measured, and blood samples were taken before breakfast. After the breakfast, a series of physical performance tests were performed. Performance tests were repeated three times during the study (PRE, MID and POST). Baseline testing was made on week 10, MID testing on week 17 and POST testing on week 21 of subjects' military service. The testing started in the morning with body composition measurements. After the breakfast, the subjects performed muscular power, strength, and muscular endurance tests. Finally, after the lunch they performed the simulated military task performance test. Every training group completed their tests during the same day.

Training programs were designed to be easy to perform during normal weekly physical training. The subjects were all from the same infantry company, and they were divided into three training groups as follows: soldier task specific training group (TSG), strength training group (STG) and control group (CON). Each group was randomly selected a platoon from the infantry company and each platoon had a total of 18 training sessions during the 12-week study with their instructor according to the specific training program (Table 5). They also conducted their normal military training every day, which consisted of road marches, shooting exercises and other task specific exercises. Variation of the instructed physical training program was due to the scheduling within the specific

MFTs. During those weeks, the conscripts were not able to do any extra physical training. The most demanding physical training sessions were performed during the lightest military training weeks. All the groups participated in the instructed physical training, but the content of training varied between the groups. All groups performed a 10-min active warm-up consisting of muscular activation before starting the actual exercise. The total length of one training session was 60 min in all groups.

TABLE 5 Design of the training protocols in the study groups.

	TASK SPECIFIC GROUP	STRENGTH TRAINING GROUP	CONTROL GROUP
Wk 1	**PRE TESTS**		
Wks 2-6	**3 x week, Task specific exercises (e.g., crawling, sprinting, military obstacle course) with combat gear (20kg) 60 min total**	**3 x week, 4 to 6 exercises, 4 x 10-15 reps (10-60%), 3 x 6-8 reps (50-75%), 3 x 3-5 reps (70-90%), 60 min total**	**3 x week, Military Physical Education (e.g., body weight training, team sports, jogging/nordic walking), 60 min total**
Wk 7	**MID TESTS**		
Wk 8	**3 x week, Task specific exercises (e.g., crawling, sprinting, military obstacle course) with combat gear (20kg) 60 min total**	**3 x week, 4 to 6 exercises, 4 x 8-10 reps (50-70%), 3 x 6-8 reps (60-80%), 3 x 3-5 reps (75-90%), 60 min total**	**3 x week, Military Physical Education (e.g., body weight training, team sports, jogging/nordic walking), 60 min total**
Wk 9	**MILITARY FIELD TRAINING**		
Wk 10	**3 x week, Task specific exercises (e.g., crawling, sprinting, military obstacle course) with combat gear (20kg) 60 min total**	**3 x week, 4 to 6 exercises, 3 x 4-6 reps (20-40%), 3 x 4-6 reps (70-90%), 2 x 3-5 reps (75-95%), 60 min total**	**3 x week, Military Physical Education (e.g., body weight training, team sports, jogging/nordic walking), 60 min total**
Wk 11	**MILITARY FIELD TRAINING**		
Wk 12	**POST TESTS**		

Task specific training group (TSG)

The task specific training group performed basic infantry-based exercises with the full combat gear (27 kg), such as sprints, crawling, casualty drag, climbing over obstacles. The exercises focused on anaerobic performance or speed. The task specific exercises performed with speed emphasis were conducted for 6 seconds, performed with maximal effort and a 2-min recovery time between the sets. The task specific exercises performed with anaerobic emphasis were conducted for 30–60 seconds for each repetition, with 75–90% of maximal effort and a 1-min recovery time between the sets (Table 5).

Strength training group (STG)
The strength training group had a non-linear training program, which included muscular endurance, hypertrophic, maximal strength and power training. Strength training started with lower loads and a higher number of repetitions (10–15 repetitions with loads of 10–60% of 1RM), but soon turned into hypertrophic (8–12 repetitions with 50–75% of 1RM), maximal strength (3–6 repetitions with 70–90% of 1RM) or power (4–6 repetitions using high speed with 20–40% of 1RM) workouts (Table 5). There were 4–5 different exercises (e.g., squat, deadlift, bench press and different push and pull exercises for upper body) in each session and 3–6 sets per exercise.

Control group (CON)
The control group trained according to the normal Finnish military physical education guidelines, which included muscular endurance training, ball games and endurance training. A normal training session included, for example, circuit training with own body weight, running with a constant pace or playing basketball, football or floorball. The total amount of their training was the same compared to the other groups (Table 5).

4.3 Data collection

4.3.1 Body composition

Body composition characteristics were measured in the morning after an overnight fast between 06:00–07:00. The subjects were instructed not to eat anything after their evening meal, which was around 19:00, but they were allowed to drink water normally. Body mass (BM), skeletal muscle mass (SMM), fat mass (FM) and fat percentage (FAT%) were measured using the segmental multi-frequency bioimpedance analysis assessment (BIA) (InBody 720, Biospace Co Ltd, Seoul, South Korea). The BIA estimates of body composition have been shown to highly correlate with the dual-energy X-ray absorptiometry (DXA) method (r = 0.82–0.95) (Sillanpää et al. 2014).

4.3.2 Maximal strength and muscular endurance

All participants were familiarized with all the present assessments either due to previous training or before the measurements. Maximal isometric force of the upper (MVCupper) and lower (MVClower) extremities were measured bilaterally in a sitting position. The measurements were conducted using an electromechanical dynamometer manufactured by the University of Jyväskylä, Jyväskylä, Finland. The knee and hip angles were set to 107° and 110°, respectively, (Viitasalo et al. 1980; Häkkinen et al. 1998) in the horizontal leg press position. The knee angle was measured using the trochanter major and the lateral malleolus as reference points. Subjects were told to ensure that they keep contact with the seat and the backrest during the test. During the measurements of upper extremities, the equipment was adjusted for each subject to their sitting position with their feet flat on the floor, the arms were parallel to the floor, and the elbow angle was 90°. The test was performed by pushing the bar horizontally. The subjects were given one trial attempt before the two actual test trials were conducted for both leg press and bench press with a minimum of 60 seconds for recovery. In both tests, the subjects were instructed to produce maximal force as fast as possible. During all trials, the testing personnel vocally encouraged participants to produce maximal effort. The best performances with regard to maximal force output in both tests were selected for further analysis.

Muscle endurance capacity of the trunk and upper extremities was measured using sit-up and push-ups tests. A test supervisor showed the proper technique for both exercises before the tests. Sit-ups were used to measure abdominal and hip flexor performance (Viljanen et al. 1991). In the starting position, the conscript laid on his back, while the legs were supported from the ankles by an assistant. The knee angle was 90°, elbows pointing upwards and fingers crossed behind the head. A successful repetition was credited when the conscript lifted his upper body from the starting position and brought elbows to the knee-level. The result was the number of successful repetitions during 60 seconds. Push-ups were used to measure performance of the arm and shoulder extensor muscles (ACSM 2000). Before taking a starting position, the conscript laid face down on the floor, feet parallel with shoulder width apart and hands positioned so that the thumbs could reach the shoulders with the other fingers pointing forward. Before the initiation of the test, the conscripts were instructed to extend their arms to the starting position and keep the feet, trunk and shoulders in the same line throughout the test. One successful repetition was counted when the soldier lowered his torso by flexing the arms to an elbow angle of 90° and returned to the starting position by extending his arms. The result was the number of successful repetitions during 60 seconds. Augustsson et al. (2009) have reported sit-ups (ICC = 0.92) and push-ups (ICC = 0.95) tests as highly repeatable.

4.3.3 Cardiorespiratory endurance

Aerobic performance was measured with a 3.2 km March Test (Kraemer et al. 2004; Santtila et al. 2010) before and after MFT. The load during the March Test was 20 kg. The test was performed on the same track both times, and the total time to complete the march was measured. The conscripts also performed a 12-min running test before MFT (Cooper 1968). It was performed on a 400 m track at garrisons.

4.3.4 Power

Countermovement jump (CMJ) was performed on a contact mat (Newtest, Oulu, Finland). Subjects were instructed to keep their hands on their hips while performing the jump. Subjects started their maximal vertical jumps from a standing position, hands on their hips. The lowest knee angle was instructed to be 90°. All the subjects had three jump attempts. The flight time from contact to contact was used to calculate the jumping height for each jump (Bosco et al. 1983).

A 6-second maximal anaerobic power cycle ergometer test (Wattbike Ltd, Nottingham, UK) was used to measure maximal power in the lower extremities. The 6-second test has a seated stationary start with the dominant leg initiating the first downstroke. Before the test, each subject's weight was inserted into the test bikes' computer and air and magnetic resistance were set accordingly. The test started following a 5-second countdown followed by verbal "go" command. The completion of the test was indicated also with another verbal "stop" command (Herbert et al. 2015).

Standing long jump (SLJ) was used to measure explosive force production of the lower extremities (Markovic et al. 2004) The jumps were performed on a 10-millimeter-thick plastic mattress designed for the purpose (Fysioline Co, Tampere, Finland). Conscripts were given instructions for proper technique, and two to three warm-up trials were performed before the actual three test attempts. The jumps were performed from a standing position, feet at pelvis to shoulder width. Take off was assisted by extension of the hip and swinging of the arms. The landing was performed bilaterally and falling backwards led to the disqualification of the attempt. The result of the best jump was measured in centimetres from the shortest distance from the landing point to the starting line. Standing long jump has been shown to be highly repeatable (ICC = 0.95) (Markovic et al. 2004).

4.3.5 Task specific fitness

Simulated military task performance

Simulated military task performance consisted of typical army soldier tasks and manoeuvres, like sprints, crawling, carrying objects, and casualty evacuation. It was performed inside on an artificial turf wearing typical combat gear, including a helmet (total extra weight of 22 kg). From the starting position of lying supine, the soldiers performed a 10 m sprint, followed by 10 m low crawl. After the low crawl, the subjects lifted, carried, and lowered two 16 kg kettlebells (CompactFit Ltd, Helsinki, Finland) twice for a distance of 10 m taking a supine position when lowering the kettlebells. This was followed by a 75 kg sandbag drag (Rogue Sandbag, Rogue Fitness Europe Ltd, Pori, Finland) for 10 m, followed by a sprint of 10 m. The total length of the track was 60 m (Figure 2).

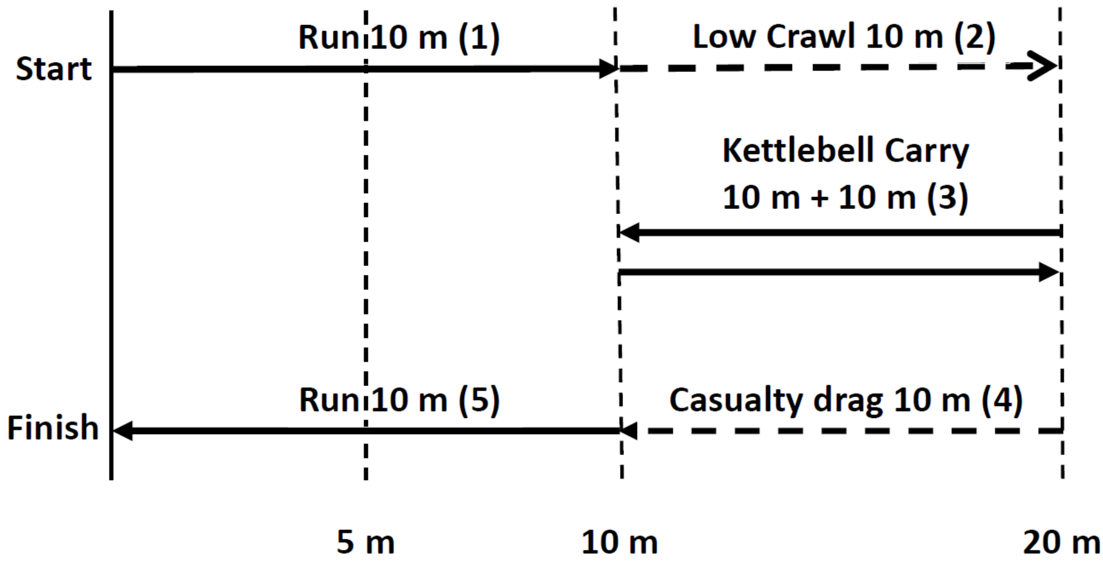

FIGURE 2 Outline of the simulated military task performance course.

The track was performed three times with a 60 second rest between the rounds. Before the simulated military task performance, subjects were individually familiarized with the track by a supervisor who also gave verbal instructions and encouraged the subjects during the test. The performance time was recorded by a stopwatch and filmed for later observation. The split times for different tasks were obtained afterwards from a video. Heart rate was recorded throughout the test by the Firstbeat team system (Firstbeat Technologies, Jyväskylä, Finland) and peak heart rate was determined from the data. Blood lactate was analysed (Biosen c-line Sport, EKF Diagnostic, Madgeburg Germany) from the fingertip (20 µl) five times (before, after each round and 10 min after the final round) from all subjects. The sensitivity for lactate was 0.5 mmol/l and inter-assay coefficient of variation was 6.2%.

Shooting
The shooting test was performed from both prone and standing positions. First, the conscripts fired ten shots at the target from a prone position and then ten shots from a standing position. The best possible score was 100 points, and the result for each person was given at an accuracy of 0.1 points. The shooting test was performed indoors, and the target was ten meters away in both prone and standing positions. The weapon system used (Eko-Aims Oy, Ylämylly, Finland) was similar to the Army assault rifle (RK95, Finland), which the conscripts handled daily. Because the tests were performed indoors, the conditions were the same in all measurement periods. The sum of ten shots from both positions was recorded for analysis.

4.3.6 Serum hormone concentrations

Venous blood samples were drawn three times into a Vacutainer® gel tube from the antecubital vein after an overnight fast between 06:30–07:30 to analyze serum concentrations of testosterone (TES), cortisol (COR), sex hormone binding globulin (SHBG), insulin-like growth factor-1 (IGF-1) and insulin-like growth factor binding protein-3 (IGFBP-3) (Siemens Immulite 2000 XPI, Siemens Healthcare, USA). The sensitivity and inter assay coefficients of variance for these assays were 0.5 nmol/l and 8.2% for TES, 5.5 nmol/l and 7.9% for COR, 0.02 nmol/l and 5.2% for SHBG, 2.6 nmol/l and 7.1% for IGF-1 and 0.3 nmol/l and 8.4% for IGFBP-3. The samples were centrifuged (Megafire 1.0 R Heraeus, DJB Lab Care, Germany) after 30 min at 2000 *g* for 10 min, frozen and transported to the laboratory for later analysis.

4.3.7 Physical activity

Physical activity was monitored using a tri-axial accelerometer (Hookie AM20, Traxmeet Ltd, Espoo, Finland). The device was attached to the waist with an elastic belt. The validity (ICC = 0.96) of the device has been reported by Vähä-Ypyä et al. (2015). The device measured several different variables including the total number of steps, running steps and intensity of activity by categorizing movement according to metabolic equivalents during each day. The subjects were instructed to keep the accelerometer on them at all times. The acceleration data was collected in raw mode (milligravity, mg). After the measurement period, the stored data were transferred to a hard disk and analyzed in 6-second epochs. Cut-points to classify activity intensity were used. The cut-points have previously been determined from adults' raw acceleration data by using mean amplitude deviation (MAD), to classify the intensity of physical activity (light, moderate, vigorous) and to separate sedentary time from physical activity (Vähä-Ypyä et al. 2015). Physical activity was analyzed and presented for the following variables: number of steps, running steps, metabolic equivalents (METs), sitting and standing time, time in light physical activity (LPA) (1.5–3.0 METs), moderate physical activity (MPA) (3.0–6.0 METs), vigorous physical activity (VPA) (> 6.0 METs) and the highest average MET in 1, 3, 10, 20 and 60 min and for the whole day.

4.4 Statistical analysis

The data for the present study was analyzed using the SPSS Statistics program (IBM SPSS 22.0–24.0, Chicago, Illinois; USA). All data were checked for normality when calculating descriptive values for all variables. Normality of distribution was assessed by the Shapiro-Wilk test. Data that did not meet the criteria for normality was log-transformed before parametric tests were applied. In each publication, for calculating descriptive statistics, means, 95% confidence intervals, standard deviations (± SD), and Pearson product moment correlation coefficients, conventional statistics were used (Studies I–IV). The effects size was calculated as the mean difference between the PRE, MID, and POST measurement values divided by the standard deviation of the values according to Cohen (1988) (0.2 =

small; 0.5 = medium; 0.8 = large effect) (Studies III–IV). The data was analyzed using multivariate analysis of variance with repeated measures. Probability adjusted *t*- tests were used for pairwise comparisons when appropriate. A general linear model, with repeated measures ANOVA with the group as a fixed factor was used to analyze time*group interaction and the differences between the different measuring points. Bivariate correlation was used for the correlation analysis where the changes in the variables between the different time points were tested. In addition, a simple regression analysis was used. The $p < 0.05$ (two-tailed) criterion was used for establishing statistical significance (Studies I–IV).

5 RESULTS

5.1 Changes in body composition, physical performance and activity, and in serum hormone concentrations during 21-day military field training

5.1.1 Body composition

BM, SMM and FM all significantly declined after MFT. Following the 4-day recovery period, the values recovered to baseline, except BM and SMM, which did not return to the PRE values. BM declined from 73.5 ± 8.7 to 71.6 ± 8.2 kg but recovered back to 73.0 ± 8.3 kg (Table 6). The same trend was also found in SMM and FM. The change in BM and in SMM negatively correlated with the change in VPA (r = –0.374 p = 0.016 and r = –0.337 p = 0.031, respectively) (Table 11).

TABLE 6 Changes in body composition during a 21-day military field training period.

Body Composition	PRE	POST	RECO
BM (kg)	73.5 ± 8.7	71.6 ± 8.2***	73.0 ± 8.3*†††
SMM (kg)	36.4 ± 3.9	35.9 ± 3.8***	36.1 ± 3.9*†††
FM (kg)	9.5 ± 4.6	8.4 ± 4.0***	9.6 ± 4.1†††
Fat %	12.6 ± 5.0	11.6 ± 4.4***	12.9 ± 4.5†††

PRE – POST 21-days, POST - RECO 4-days. Abbreviations: PRE, Before training measurements; POST, Post training measurements; RECO, Recovery measurements; BM, Body mass; SMM, Skeletal muscle mass; FM, fat mass; *, †, ‡ = p < 0.05; **, ††, ‡‡ = p < 0.01; ***, †††, ‡‡‡ = p < 0.001; *, **, ***, compared to the PRE values; †, ††, ††† = compared to the MID values; ‡, ‡‡, ‡‡‡ = compared to POST values.

5.1.2 Physical performance

As Table 7 demonstrates sit-ups declined from the PRE values (46 ± 9 reps/min) to both MID (40 ± 8 reps/min) and POST (42 ± 8 reps/min) measurement points (p < 0.001) and declined even more for RECO (34 ± 11 reps/min) measurement. In push-ups, declines in the POST (34 ± 10 reps/min) and RECO (34 ± 13 reps/min) measurements (p < 0.001) from the PRE (40 ± 13 reps/min) and MID (39 ± 12 reps/min) values were observed. Standing long jump declined in MID (220 ± 20 cm), POST (216 ± 20 cm) and RECO (213 ± 20 cm) as compared to the PRE (229 ± 23 cm) values (p < 0.001). In addition, there was a decline from MID to POST (p < 0.01) and from POST to RECO (p < 0.05). There was no change (p > 0.05) in 3.2 km loaded march time between the PRE (23:57±4:12 min:s) and POST (23:44±5:02 min:s) measurement points.

TABLE 7 Changes in physical performance during a 21-day military field training period.

	PRE	MID	POST	RECO
Sit-ups (reps/min)	46 ± 9	40 ± 8***	42 ± 8***	34 ± 11***†††‡‡‡
Push-ups (reps/min)	40 ± 13	39 ± 12	34 ± 10***†††	34 ± 13**†
Standing long jump (cm)	229 ± 23	220 ± 20***	216 ± 20***††	213 ± 20***†††‡
3.2 km march time (min:s)	23:57 ± 4:12		23:44 ± 5:04	

PRE – MID 14 days, PRE – POST 21-days, POST - RECO 4-days. Abbreviations: PRE, Before training measurements; MID, halfway training measurements; POST, Post training measurements; RECO, Recovery measurements; *, †, ‡ = p < 0.05; **, ††, ‡‡ = p < 0.01; ***, †††, ‡‡‡ = p < 0.001; *, **, ***, compared to the PRE values; †, ††, ††† = compared to the MID values; ‡, ‡‡, ‡‡‡ = compared to POST values.

There was a significant increase (p < 0.05) in isometric leg press force from the MID of 3406 ± 923 N to POST 3532 ± 1011 N measurement. No other significant changes were found in leg press. Maximal force of upper body isometric bench press increased significantly (p < 0.001) from PRE of 890 ± 181 N to MID 929 ± 179 N. There was a decline in POST of 900 ± 179 N (p < 0.05) and RECO 873 ± 178 N (p < 0.001) measurements when compared to MID 929 ± 179 N. RECO 873 ± 178 N (p < 0.001) was also significantly lower than POST of 900 ± 179 N measurement (Table 8).

TABLE 8 Mean (± SD) values of isometric force and shooting tests during a 21-day military field training period.

Isometric-force	**PRE**	**MID**	**POST**	**RECO**
Bench press (N)	890 ± 181	929 ± 179***	900 ± 179†	873 ± 178*†††‡‡‡
Leg press (N)	3495 ± 931	3406 ± 923	3532 ± 1011†	3424 ± 913
Shooting	**PRE**	**MID**	**POST**	**RECO**
Prone (points)	84.3 ± 11.7	85.5 ± 9.1	84.8 ± 11.5	87.2 ± 11.0
Standing (points)	58.2 ± 12.3	45.2 ± 10.4**	61.4 ± 10.8††	56.8 ± 13.6†††‡

PRE – MID 14 days, PRE – POST 21-days, POST - RECO 4-days. Abbreviations: PRE, Before training measurements; MID, halfway training measurements; POST, Post training measurements; RECO, Recovery measurements *, †, ‡ = p < 0.05, †† = p < 0.01, ***, †††, ‡‡‡ = p < 0.001; *, *** = compared to PRE values, ††, ††† = compared to MID values, ‡, ‡‡‡ = compared to POST values.

5.1.3 Physical activity

Table 9 demonstrates that the total number of steps per day was significantly ($p < 0.001$) greater during ST (13722 ± 2379 steps) and MFT (13937 ± 2276 steps) than during the garrison days (9550 ± 2569 steps). Running steps were linked to the daily program and were higher during the PRE measurements because of strenuous physical training. There was significantly ($p < 0.001$) more light (1.5–3.0 MET) (2:34:38 ± 0:22:53 h:min:s in ST, and 3:03:27 ± 0:23:24 h:min:s in MFT) and moderate (3.0–6.0 MET) (2:12:15 ± 0:23:14 h:min:s in ST, and 2:47:59 ± 0:27:23 h:min:s in MFT) physical activity during ST and MFT than in the PRE measurements. Vigorous physical activity (> 6.0 MET) was significantly lower during MFT (3:35 ± 1:52 min:s) than during PRE (12:42 ± 10:03 min:s), ST (12:50 ± 5:39 min:s) and RECO (10:13 ± 6:35 min:s). Also, the number of running steps was higher during the ST (1306 ± 502 steps) and PRE (9550 ± 2569 steps) measurements compared to MFT (381 ± 205 steps) and RECO (415 ± 266 steps). The highest average MET values were found during ST, when looking at 1-, 3-, 10-, 20- or 60-min time period. The highest daily average was found during MFT. There were no correlations in the changes between physical activity and changes in physical performance. The Ratio of Perceived Exertion (RPE) was significantly ($p < 0.001$) higher during MFT, and the conscripts slept more ($p < 0.001$) during MFT than at the other measurement points.

TABLE 9 Changes in physical activity, sleep and RPE during a 21-day military field training period.

	PRE	**ST**	**MFT**	**RECO**
Sitting (h:min:s)	7:11:18 ± 1:05:28	8:27:38 ± 1:10:57***	7:56:54 ± 0:50:10**††	5:53:26 ± 1:38:09***†††‡‡‡
Standing (h:min:s)	2:32:49 ± 0:53:06	2:21:19 ± 0:38:37	2:18:00 ± 0:29:26*	1:58:19 ± 0:38:20***†††‡‡
MET 1.5–3.0 (h:min:s)	1:44:49 ± 0:20:03	2:34:38 ± 0:22:53***	3:03:27 ± 0:23:24***†††	1:40:17 ± 0:22:22†††‡‡‡
MET 3.0–6.0 (h:min:s)	1:23:16 ± 0:22:02	2:12:15 ± 0:23:14***	2:47:59 ± 0:27:23***†††	1:08:03 ± 0:14:48***†††‡‡‡
MET> 6 (h:min:s)	0:12:42 ± 0:10:03	0:12:50 ± 0:05:39	0:03:35 ± 0:01:52***†††	0:10:13 ± 0:06:35††‡‡‡
Steps	9550 ± 2569	13722 ± 2379***	13937 ± 2276***	7974 ± 1803**†††‡‡‡
Running steps	699 ± 658	1306 ± 502***	381 ± 205**†††	415 ± 266***†††
MET1min	9.18 ± 2.38	9.95 ± 1.41*	7.59 ± 1.08***†††	8.12 ± 1.88*†††
MET3min	6.58 ± 1.01	7.93 ± 1.14***	5.61 ± 0.61***†††	6.21 ± 1.01†††‡‡‡
MET10min	4.47 ± 0.58	5.82 ± 0.86***	4.21 ± 0.27**†††	4.30 ± 0.48†††
MET20min	3.05 ± 0.52	4.21 ± 0.58***	3.39 ± 0.17***†††	3.01 ± 0.33†††‡‡‡
MET60min	2.54 ± 0.47	3.38 ± 0.42***	2.96 ± 0.14***†††	2.44 ± 0.24†††‡‡‡
METday	1.49 ± 0.02	1.56 ± 0.01***	1.60 ± 0.01***†	1.48 ± 0.12†††‡‡‡
Questionnaires	PRE	ST	MFT	RECO
Sleep (h)	5.7 ± 0.6	5.6 ± 0.8	6.1 ± 0.8**†††	5.7 ± 1.2‡
RPE	8.4 ± 1.4	10.2 ± 1.6***	9.4 ± 1.5**††	7.1 ± 1.3***†††‡‡‡

Abbreviations: PRE, Pre measurements; ST, Shooting training; MFT, Military field training; RECO, Recovery measurements; RPE, Rate of perceived exertion; *, †, ‡ = p < 0.05; **, ††, ‡‡ = p < 0.01; ***, †††, ‡‡‡ = p < 0.001; *, **, ***, compared to the PRE values; †, ††, ††† = compared to the MID values; ‡, ‡‡, ‡‡‡ = compared to POST values.

5.1.4 Serum hormone concentrations

Testosterone

Serum TES concentrations decreased significantly ($p < 0.001$) from PRE 18.5 ± 4.5 nmol/l to MID 13.8 ± 4.9 nmol/l (–25.0%) and POST 16.0 ± 4.2 nmol/l (–13.0%). The POST value was also significantly higher than the MID ($p < 0.01$, 15.9%). The value of RECO 19.9 ± 3.7 nmol/l was significantly higher than ($p < 0.001$, 44.2%) MID and POST (24.4%) and also higher than PRE ($p < 0.05$, 8.2%) (Table 10).

Cortisol

There was a significant increase in serum COR concentrations between PRE 301 ± 86 nmol/l and MID 355 ± 76 nmol/l ($p < 0.05$, 17.8%), POST 396 ± 69 nmol/l ($p \leq 0.001$, 31.3%) and RECO 385 ± 85 nmol/l ($p < 0.001$, 27.8%). Also, in POST, the COR concentration was significantly ($p < 0.001$, 11.5%) higher that in MID (Table 10).

Insulin-like growth factor-1

IGF-1 concentration showed a significant ($p \leq 0.001$) reduction from PRE of 40.6 ± 7.7 nmol/l to MID 32.5 ± 8.9 nmol/l (–20.0%) and POST 32.5 ± 7.7 nmol/l (–20.0%). Also, a significant increase of the same magnitude ($p \leq 0.001$) was observed between RECO of 39.4 ± 7.8 nmol/l and MID (21.2%) and POST (21.2%) (Table 10).

Sex hormone binding globulin (SHBG)

There was a significant increase in SHBG concentration from PRE of 30.1 ± 7.6 nmol/l to MID 32.8 ± 7.9 nmol/l ($p < 0.01$, 9.0%) and POST of 34.3 ± 9.1 nmol/l ($p < 0.001$, 14.0%). A significant ($p < 0.001$) decline was observed between POST and RECO 31.5 ± 8.1 nmol/l (–8.2%) (Table 10).

TABLE 10 Mean (± SD) serum hormone concentrations and SHBG concentrations during a 21-day military field training period.

	PRE	MID	POST	RECO
TES (nmol/l)	18.4 ± 4.5	13.8 ± 4.9**	16.0 ± 4.2**††	19.9 ± 3.7*†††‡‡‡
COR (nmol/l)	301 ± 86	355 ± 76*	396 ± 69**††	385 ± 85***
IGF-1 (nmol/l)	40.6 ± 7.7	32.5 ± 8.9**	32.5 ± 7.7**	39.4 ± 7.8†††‡‡‡
SHBG (pmol/l)	30.1 ± 7.6	32.8 ± 7.9*	34.3 ± 9.1**	31.5 ± 8.1‡‡‡

PRE – MID 14 days, PRE – POST 21-days, POST - RECO 4-days. Abbreviations: PRE, Before training measurements; MID, halfway training measurements; POST, Post training measurements; RECO, Recovery measurements; TES, Testosterone; COR, Cortisol; IGF-1, Insulin-like growth factor 1; SHBG, Sex hormone-binding globulin. * = $p < 0.05$, **, †† = $p < 0.01$, ***, †††, ‡‡‡ = $p < 0.001$; *, **, *** = compared to PRE values, †, ††, ††† = compared to MID values, ‡, ‡‡, ‡‡‡ = compared to POST values.

5.1.5 Military performance

There was no change in the prone shooting score between the measuring points. In the standing position, however, there was a significant ($p < 0.001$) decrease from PRE 58.2 ± 12.3 points to MID 45.2 ± 10.4 points. Also POST of 61.4 ± 10.8 points and RECO of 56.8 ± 13.6 points were significantly ($p < 0.001$) higher than MID of 45.2 ± 10.4 points. (Table 8)

5.1.6 Associations between body composition, physical tests, and physical activity

Individual changes in lower body strength and changes in the standing shooting score between the measurement points (PRE - MID / POST / RECO) correlated significantly (r = 0.332, p = 0.031; r = 0.335, p = 0.025; r = 0.489, p = 0.001, respectively). The same was found with changes in upper body strength and changes in standing shooting between the PRE and RECO measurement points (r = 0.339, p = 0.010). With regard to serum concentrations, negative correlations were observed between the changes in SHBG and changes in IGF-1 in all measurement points (r = –0.310, p = 0.043; r = –0.482, p = 0.001; r = –0.382, p = 0.010). There was also a positive correlation between the changes in SHBG and the change in TES (r = –0.330, p = 0.027) when comparing the PRE and RECO measurement points. The changes in COR negatively correlated with the changes in TES (r = –0.341, p = 0.025) and the changes in IGF-1 (r = –0.346, p = 0.023) between the PRE and MID measurement points. The changes in COR and the changes in prone shooting showed positive correlations in all measurement points (r = 0.531, $p < 0.001$; r = 0.337, p = 0.024; r = 0.572, $p < 0.001$). The changes in IGF-1 negatively correlated (r = –0.325, p = 0.038) with prone shooting between the PRE and MID measurement points. The changes in standing shooting and the changes in TES between PRE and POST were negatively correlated (r = –0.378, p = 0.010). The changes in RPE compared to the changes in in the push-up test correlated also significantly (r = –0.408, p = 0.007) (Table 11). There were no significant correlations between RPE and other muscle endurance tests or body composition.

TABLE 11 Correlation coefficients between the relative changes in muscular endurance, aerobic performance and body composition compared to relative changes in physical activity, sleep and RPE during a 21-day military field training period.

	Sit-ups		**Push-ups**		**Standing long jump**		**3.2 km march**		**BM**		**SMM**		**FM**	
	r	p	r	p	r	p	r	p	r	p	r	p	r	p
LPA	0.004	0.981	0.097	0.552	0.051	0.750	−0.126	0.458	−0.19	0.417	−0.035	0.826	−0.09	0.574
MPA	0.017	0.918	−0.158	0.329	−0.120	0.455	0.058	0.732	−0.213	0.180	−0.234	0.140	−0.029	0.858
VPA	0.092	0.566	0.109	0.502	−0.117	0.466	0.010	0.952	*−0.374*	*0.016 **	*−0.337*	*0.031 **	−0.086	0.593
Steps	0.137	0.392	−0.128	0.433	−0.186	0.243	−0.210	0.213	−0.226	0.156	−0.219	0.169	−0.095	0.553
Sleep	0.007	0.965	−0.001	0.996	−0.062	0.686	0.053	0.741	0.073	0.632	0.194	0.203	−0.109	0.477
RPE	0.077	0.626	*−0.408*	*0.007***	0.166	0.287	0.182	0.262	−0.031	0.842	−0.005	0.977	0.001	0.994

Abbreviations: LPA, low physical activity; MPA, medium physical activity; VPA, vigorous physical activity; RPE, rate of perceived exertion; BM, Body mass; SMM, Skeletal muscle mass; FM, fat mass; *= $p < 0.05$; ** = $p < 0.01$.

5.2 Changes in body composition, physical performance, and in serum hormone concentrations during the 12-week strength and military task specific training interventions

5.2.1 Body composition

Significant increases from PRE to POST and MID to POST were found in body mass in the STG (1.5 ± 2.8% and 0.8 ± 1.7%) (Table 12). In addition, significant increases were found in SMM between the PRE and MID measurement points in the TSG (1.7 ± 3.0%) and STG (1.0 ± 1.9%). A significant drop in FM was observed in the TSG (–9.5 ± 13.5%) between the PRE and MID measurements, but FM (11.1 ± 21.7%) recovered almost back to the PRE values from the MID to POST measurements. No significant differences were observed between the groups at any measurement points.

5.2.2 Physical performance

In the strength and power performances, most of the significant increases took place in the TSG and STG, both during the first part and after the entire experimental training period (Table 13). Isometric leg press force increased significantly by 7.9 ± 12.2% ($p < 0.05$) for TSG and by 7.1 ± 12.6% ($p < 0.05$) for STG between the PRE and MID measurements. A significant increase of 8.1 ± 12.4% ($p < 0.05$) in leg press force was also observed in TSG and STG of 12.3 ± 15.3% ($p<0.01$) between the PRE and POST measurements. Isometric horizontal bench press force increased significantly by 4.7 ± 6.8% ($p < 0.01$) between the PRE and MID and by 7.1 ± 7.0% ($p < 0.01$) between the PRE and POST measurements. Maximal power in the 6-second cycling test increased significantly between PRE and MID by 4.4±6.9% ($p<0.05$) in TSG and 4.1 ± 4.8% ($p < 0.01$) in STG as well as between the PRE and POST measurements in TSG 6.0 ± 6.3% ($p < 0.05$), in STG 4.1 ± 5.3% ($p < 0.01$) and in CON group 5.3 ± 5.5% ($p < 0.01$). In push-ups, there were significant increases between the PRE and MID measurements in TSG 26.5 ± 33.4% ($p < 0.01$) and in STG 14.0 ± 13.1% ($p < 0.05$). Between PRE and POST, the CON group improved significantly by 31.0 ± 26.9% ($p < 0.01$) its push-ups performance. No significant differences were observed between the groups in the PRE measurements. The CON group differed significantly from the TSG and STG in lower body strength in the MID and POST measurements and also in standing long jump in the POST measurement point.

TABLE 12 Mean (± SD) values of body composition in the study groups.

		PRE		MID		POST		|Effect size|		
	Group	**Mean ± SD**	**95% CI**	**Mean ± SD**	**95% CI**	**Mean ± SD**	**95% CI**	**1vs2**	**2vs3**	**1vs3**
	TSG	74.6 ± 10.4	69.6; 79.6	74.3 ± 9.7	69.7; 79.0	74.8 ± 9.4	70.2; 79.3	0.03	0.05	0.02
BM (kg)	STG	72.3 ± 7.7	68.5; 76.0	72.7 ± 7.5	69.1; 76.3	73.3 ± 7.9 #, §	69.5; 77.1	0.05	0.08	0.13
	CON	70.3 ± 10.2	63.8; 76.7	69.8 ± 9.0	64.1; 75,5	70.1 ± 8.3	64.8; 75.3	0.05	0.03	0.02
	TSG	36.7 ± 4.8	34.4; 39.0	37.3 ± 4.7*	35.0; 39.6	37.1 ± 4.8#	34.8; 39.4	0.12	0.04	0.08
SMM (kg)	STG	37.0 ± 4.1	35.1; 38.9	37.4 ± 4.0*	35.5; 39.3	37.5 ± 4.1	35.5; 39.4	0.10	0.02	0.12
	CON	34.7 ± 4.3	31.9; 37.4	34.8 ± 4.4	32.0; 37.5	34.8 ± 4.5	31.9; 37.6	0.02	0.00	0.02
	TSG	10.1 ± 4.6	7.9; 12.2	8.9 ± 3.7*	7.1; 10.7	9.7 ± 3.7§§	7.9; 11.5	0.28	0.21	0.09
FM (kg)	STG	7.3 ± 2.8	6.0; 8.6	7.2 ± 2.9	5.9; 8.6	7.9 ± 3.1§§§	6.4; 9.3	0.03	0.23	0.20
	CON	9.2 ± 5.1	6.0; 124	8.7 ± 4.3	6.0; 11.4	8.9 ± 3.7	6.6; 11.3	0.10	0.05	0.07
	TSG	13.3 ± 4.7	11.0; 15.5	11.9 ± 3.9*	10.0; 13.8	12.9 ± 4.1§§	10.9; 14.9	0.32	0.24	0.09
FAT%	STG	10.1 ± 3.5	8.4; 11.7	9.9 ± 3.5	8.2; 11.5	10.6 ± 3.6§§§	8.9; 12.3	0.06	0.19	0.14
	CON	12.6 ± 5.7	9.0; 16.3	12.3 ± 5.4	8.9; 15.7	12.7 ± 4.6	9.7; 15.6	0.05	0.08	0.02

PRE – MID 6 weeks, PRE – POST 12 weeks, MID – POST 6 weeks. BM, body mass; SMM, skeletal muscle mass; FM, fat mass; FAT%, fat percentage; TSG, task specific training group; STG, strength training group; CON, control group. * = PRE to MID values *=p < 0.05; # = PRE to POST values, #=p < 0.05, MID to POST values §= p < 0.05, §§=p < 0.01, §§§ < 0.001.

TABLE 13 Mean (± SD) strength and power performance values in the study groups.

		PRE		MID		POST		|Effect size|		
	Group	Mean ± SD	95% CI	Mean ± SD	95% CI	Mean ± SD	95% CI	1vs2	2vs3	1vs3
CMJ (cm)	TSG	30 ± 5	27; 32	29 ± 5	27; 31	31 ± 4$^{**, \#\#\#}$	29; 33	0.20	0.43	0.22
	STG	32 ± 6	29; 35	33 ± 5	30; 35	34 ± 5	32; 36	0.18	0.20	0.35
	CON	31 ± 6	28; 35	30 ± 7*	25; 34	31 ± 6	28; 35	0.15	0.15	0.00
POWER MAX (w)	TSG	1038 ± 153	964; 1112	1075 ± 152*	1002; 1149	1096 ± 141$^{*, \#\#}$	1028; 1164	0.24	0.14	0.39
	STG	1070 ± 112	1012; 1119	1119 ± 120**	1054; 1159	1120 ± 126**	1051; 1165	0.41	0.01	0.41
	CON	952 ± 104	896; 1040	992 ± 136	905; 1078	1017 ± 139**	928; 1105	0.32	0.18	0.51
UPPER BODY STRENGTH (kg)	TSG	79 ± 16	71; 86	77 ± 14	70; 83	80 ± 13$^{\#\#\#}$	74; 87	0.13	0.22	0.07
	STG	77 ± 15	70; 84	82 ± 16**	72; 88	82 ± 17**	74; 90	0.32	0.00	0.31
	CON	72 ± 15	64; 83	73 ± 12	70; 83	76 ± 15	65; 86	0.07	0.21	0.26
LOWER BODY STRENGTH (kg)	TSG	240 ± 46	219; 263	255 ± 49*	232; 279	263 ± 48**	240; 286	0.32	0.16	0.48
	STG	227 ± 46	205; 248	240 ± 37*	222; 257	240 ± 38*	222; 258	0.31	0.00	0.30
	CON	214 ± 51	182; 247	220 ± 61 µ	181; 259	222 ± 60 µ	184; 261	0.10	0.03	0.14
STANDING LONG JUMP (cm)	TSG	216 ± 25	204; 228	215 ± 21	205; 225	216 ± 21	205; 226	0.04	0.05	0.00
	STG	228 ± 17	220; 237	228 ± 18	218; 233	229 ± 17	220; 235	0.00	0.06	0.06
	CON	214 ± 32	194; 234	210 ± 28	192; 228	210 ± 31µ	190; 229	0.13	0.00	0.12
SIT-UPS (reps/min)	TSG	41 ± 10	36; 45	42 ± 9	37; 46	40 ± 12	34; 46	0.10	0.18	0.09
	STG	44 ± 9	39; 48	45 ± 8	40; 48	45 ± 9	40; 48	0.12	0.00	0.11
	CON	41 ± 7	36; 46	43 ± 8	38; 48	42 ± 7	37; 47	0.26	0.13	0.14
PUSH-UPS (reps/min)	TSG	34 ± 13	28; 40	40 ± 14**	33; 47	38 ± 15	31; 45	0.43	0.13	0.28
	STG	38 ± 12	32; 44	43 ± 13*	36; 48	41 ± 14	34; 47	0.39	0.23	0.15
	CON	35 ± 14	25; 45	41 ± 15	29; 50	44 ± 16**	33; 54	0.40	0.19	0.58

PRE – MID 6 weeks, PRE – POST 12 weeks, MID – POST 6 weeks. CMJ, counter measurement jump; POWER MAX, maximal 6 s power cycling; POWER AVE, average 6 s power cycling; UPPER BODY STRENGTH in maximal isometric action; LOWER BODY STRENGTH in maximal isometric action; TSG, task specific training group; STG, strength training group; CON, control group. * = PRE to MID values * = p < 0.05; # = PRE to POST values, # = p < 0.05, ##=p < 0.01, ### < 0.001, MID to POST values § = p < 0.05, §§ = p < 0.01, §§§ < 0.001; between the groups, µ = p < 0.05

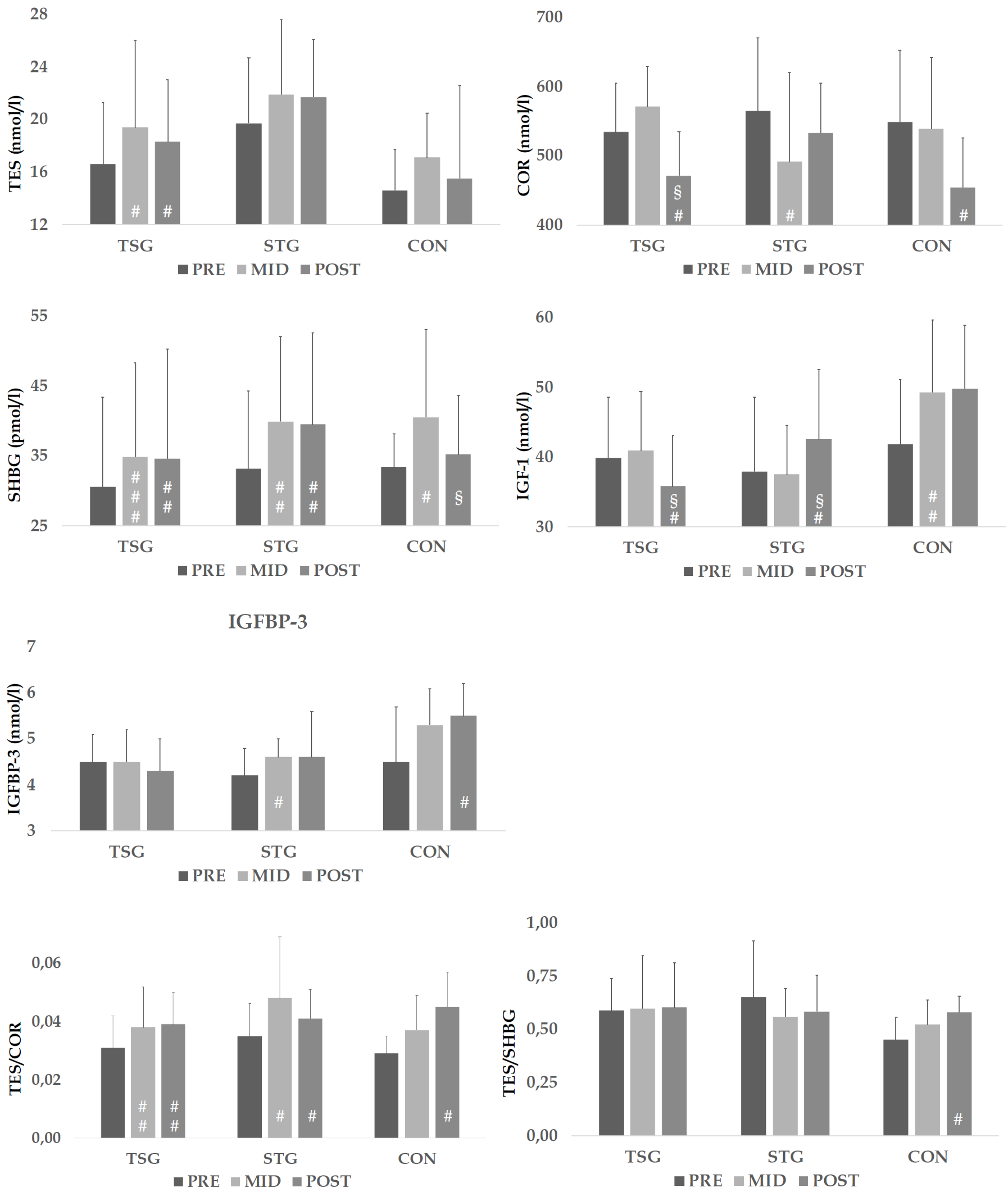

FIGURE 3 Serum hormone concentrations during the 12- week intervention study.

PRE – MID 6 weeks, PRE – POST 12 weeks, MID – POST 6 weeks. TSG, task specific training group; STG, strength training group; CON, control group; TES, testosterone; COR, cortisol; SHBG, sex-hormone binding globulin; IGF-1 insulin-like growth factor 1; IGFBP-3, insulin-like growth factor binding protein 3; TES/COR, testosterone – cortisol ratio; TES/SHBG, testosterone – sex-hormone binding globulin. Within the groups; # = $p < 0.05$, ## = $p < 0.01$, ### = $p < 0.001$, compared to PRE value; § = $p < 0.05$, compared to MID value.

5.2.3 Serum hormone concentrations

Serum TES concentration increased significantly in TSG between the PRE and MID (16.8 ± 33.9%) and PRE and POST (11.2 ± 16.7%) measurements (Figure 3). Serum COR concentrations decreased in TSG between the MID and POST (–7.8 ± 10.9%) and PRE and POST (–11.0 ± 14.3%) measurements. In the CON group, a decrease in COR concentration was found between PRE and POST (–16.3 ± 14.8%). Serum SHBG concentrations increased both in the TSG and STG between PRE and MID (18.2 ± 19.6% for TSG and 24.9 ± 30.3 for STG) and between PRE and POST (11.0 ± 17.4% for TSG and 23.5 ± 38.2% for STG). In the CON group, SHBG first increased significantly (20.0 ± 32.9%) between PRE and MID and then decreased significantly (–5.8 ± 25.2%) between MID and POST. The IGF-1 concentration decreased in TSG between MID and POST (–11.1 ± 15.1%) and PRE and POST (–7.7 ± 16.0%). The CON group showed significant increases in IGF-1 between PRE and MID (10.5 ± 10.9%). The IGFBP-3 concentration increased significantly in STG between PRE and MID (9.8 ± 14.4%) and in the CON group between PRE and POST (29.5 ± 46.2%). The TES/COR-ratio increased significantly in all groups between PRE and MID and PRE and POST, while a significant change was only observed between PRE and POST in the CON group.

5.2.4 Military performance

Maximal isometric strength produced during the bilateral leg press increased significantly between the PRE and MID (7.9 ± 12.2%) and PRE and POST (12.3 ± 15.3%) measurements in TSG, but not in the STG and CON groups. Maximal isometric strength during the bilateral bench press increased significantly in STG between the PRE and MID (4.7 ± 6.8%) and PRE and POST (7.1 ± 7.1%) measurements. In TSG, a significant increase occurred between the MID and POST (4.8 ± 4.3%) measurements. No significant differences between the groups were observed in these changes in maximal isometric forces. In all groups, significant increases occurred in 6 s maximal anaerobic power in the cycle ergometer test between PRE and POST (Table 14). TSG and STG also showed significant increases in power between the PRE and MID measurements, but the CON group showed no changes. In CMJ, a significant increase occurred in jump height between PRE and POST (5.7 ± 8.7%) in TSG and between MID and POST (7.7 ± 7.3%) in TSG. No significant differences were observed between the groups in the changes in CMJ.

The total time of the first trial in the simulated military task performance improved in TSG and STG between the PRE and MID measurements by 11.1% (ES = 0.64) and 9.4% (ES = 0.91) and between the PRE and POST measurements by 11.4% (ES = 0.74) and 8.8% (ES = 0.72), respectively. No significant changes were observed in CON group between the measurements in the first trial. In the second trial, the total time improved significantly in TSG and STG between the PRE and MID measurements by 14.6% and 13.1%. All groups showed significant improvements between the PRE and POST measurements (TSG: 17.0%, STG: 14.1%, and CON: 12.0%, ES = 1.35, 1.12, and 0.76, respectively). There was also a significant improvement in CON between the MID and POST measurements (6.3%, ES = 0.36). A similar trend was also observed in the third trial. A significant improvement was found between the PRE and MID measurements in TSG (14.6%, ES = 0.78) and STG (15.7%, ES = 1.05), but not in the CON group (2.1%, ES = 0.08). Between the PRE and POST measurements, a significant improvement occurred in all groups (TSG 19.2%, ES = 1.01, STG 18.2%, ES = 1.23, and CON 12.1%, ES = 0.77). TSG and CON group showed significant improvements between the MID and POST measurements (TSG 5.3%, ES = 0.32, and CON 9.6%, ES = 0.52; Figure 4).

TABLE 14 Mean (± SD), 95% confidence interval (CI), and effect size values in the maximal neuromuscular tests in the PRE, MID, and POST measurements.

		PRE		MID		POST		|Effect Size|		
	Group	**Mean ± SD**	**95% CI**	**Mean ± SD**	**95% CI**	**Mean ± SD**	**95% CI**	**1vs2**	**2vs3**	**1vs3**
CMJ (cm)	TSG	29 ± 6	26; 32	29 ± 5	26; 31	31 ± 4 *, #	28; 33	0.00	0.43	0.38
	STG	33 ± 6	29; 36	33 ± 5	30; 36	35 ± 4	32; 37	0.00	0.43	0.38
	CON	32 ± 6	28; 36	31 ± 7	26; 35	31 ± 6	27; 35	0.15	0.00	0.16
POWER (w)	TSG	1036 ± 140	961; 1110	1078 ± 138 *	1004; 1151	1094 ± 125 **	1027; 1160	0.30	0.12	0.43
	STG	1097 ± 98	1043; 1152	1140 ± 92 *	1090; 1192	1141 ± 103 *	1084; 1198	0.44	0.01	0.43
	CON	974 ± 122	886; 1061	1007 ± 144	904; 1110	1027 ± 147 *	922; 1132	0.24	0.13	0.38
UPPER BODY (kg)	TSG	78 ± 14	71; 86	77 ± 13	70; 84	80 ± 12 ##	74; 87	0.07	0.23	0.15
	STG	79 ± 14	72; 87	83 ± 14 *	75; 90	84 ± 14 **	77; 92	0.28	0.06	0.35
	CON	75 ± 14	65; 85	75 ± 15	65; 86	77 ± 16	65; 88	0.00	0.17	0.18
LOWER BODY (kg)	TSG	236 ± 40	214; 257	252 ± 39 *	231; 273	255 ± 50 **	239; 284	0.40	0.07	0.41
	STG	229 ± 49	202; 256	242 ± 39	221; 264	244 ± 39	223; 266	0.29	0.05	0.33
	CON	224 ± 50	189; 260	234 ± 57	193; 275	236 ± 56	195; 276	0.18	0.03	0.22

PRE – MID 6 weeks, PRE – POST 12 weeks, MID – POST 6 weeks. CMJ, countermovement jump; POWER, maximal 6 s power cycling; UPPER BODY STRENGTH, maximal isometric bilateral extension; LOWER BODY STRENGTH, maximal bilateral extension; TSG, task specific training group; STG, strength training group; CON, control group. * = compared to PRE values * = $p < 0.05$, ** = $p < 0.01$; # = compared to MID values, # = $p < 0.05$, ## < 0.01.

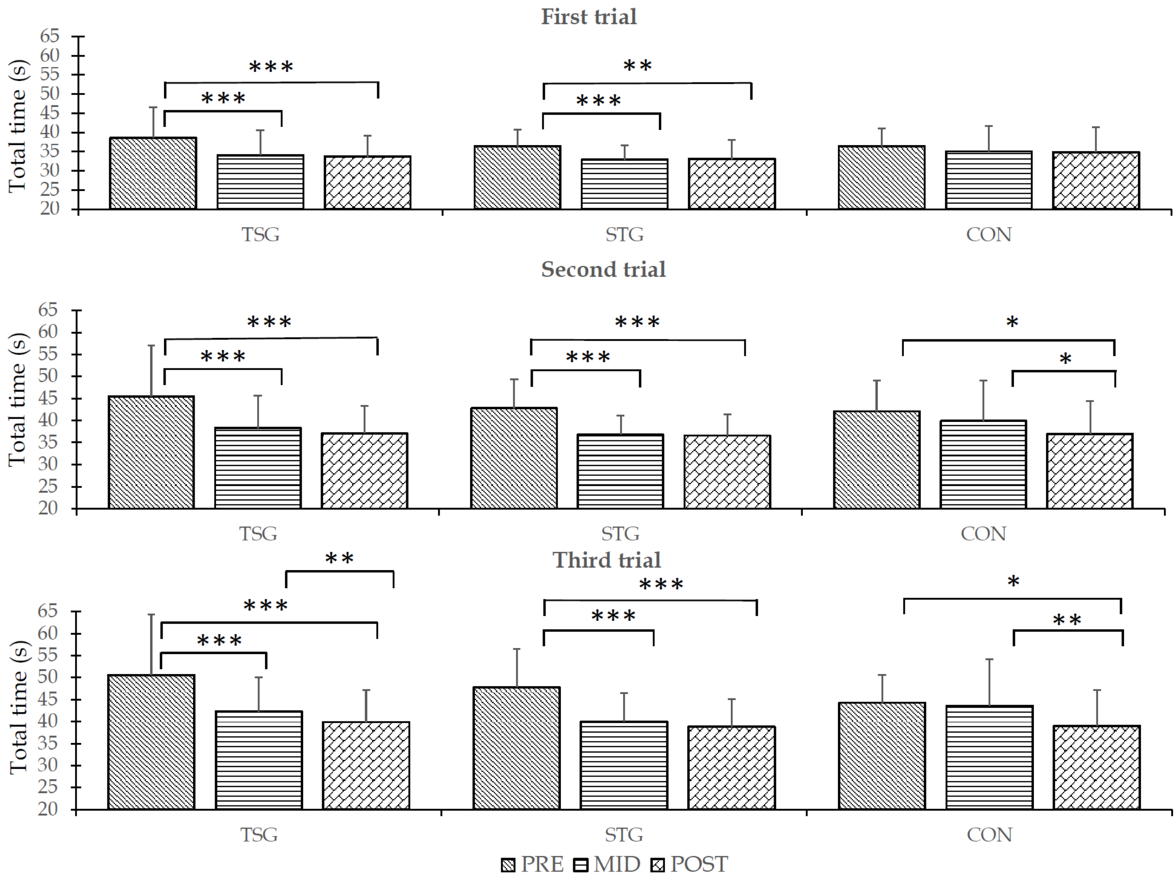

FIGURE 4 Total time (s) in the simulated military task course (first, second, and third trial). PRE – MID 6 weeks, PRE – POST 12 weeks, MID – POST 6 weeks. TSG = task specific training group; STG = strength training group; CON = control group; * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

No significant changes were found in running time over the first 5 m during the first trial (Table 15). During the second trial, TSG and CON group significantly improved between the PRE and POST measurements (Table 16). In the third trial, TSG and STG significantly improved between PRE and MID. CON group improved significantly only between the PRE and POST measurements (Table 17).

TSG and STG significantly improved their time in the first trial between the PRE and MID and PRE and POST measurements (Table 15). In the second trial, TSG and STG improved crawling time between PRE and MID and between PRE and POST. CON group improved crawling time between the PRE and POST measurements. TSG and CON group also improved their time between MID and POST (Table 16). In the 3rd run, TSG and STG improved crawling time between PRE and MID and between PRE and POST. CON group improved it's time between PRE and POST. Between MID and POST, there was a significant improvement in the TSG and CON groups (Table 17).

TSG and STG improved carry time in the first trial between the PRE and MID measurements. TSG also improved its time between the PRE and POST measurements (Table 15). In the second trial, TSG and STG improved their carry time between PRE and MID and between PRE and POST. The CON group also improved its time between the PRE and POST measurements. The STG and CON groups improved their time between the MID and POST measurements (Table 16). TSG and STG improved their carry time in the third trial between PRE and MID and PRE and POST. The CON group also improved its time between the PRE and POST measurements. The STG and CON groups improved their time between the MID and POST measurements (Table 17).

In 75 kg mannequin drag, there were improvements in the first trial in TSG and STG between the PRE and MID and PRE and POST measurements. (Table 15) Similar results were also observed between the PRE and MID measurements in TSG and STG in the second trial (Table 16) and in the third trial (Table 17), and between PRE and POST in the second trial (Table 16) and in the third trial (Table 17). No significant changes in the mannequin drag were found in CON group.

There were significant improvements during the first trial in TSG and STG between PRE and MID and PRE and POST (Table 15). Furthermore, during the second trial, there were significant improvements in TSG and STG between PRE and MID and PRE and POST. In addition, the CON group improved its time between PRE and POST (Table 16). In the third trial, TSG improved its time between PRE and MID and between PRE and POST. STG showed an improvement between PRE and POST (Table 17).

Blood lactate and heart rate increased throughout the simulated military task performance in all measurement points. The highest values in blood lactate were measured in the POST measurement in all groups (ranging from 15.08 to 16.90 mmol/l). Mean heart rate varied between 172 and 182 bpm during the simulated military task performance.

TABLE 15 Simulated military task performance times for different tasks (first 5 m run, crawl, kettlebell carry (KB), casualty drag, and final 10 m run) from the first trial in the PRE, MID, and POST measurements points. PRE – MID 6 weeks, PRE – POST 12 weeks, MID – POST 6 week

First Trial		**PRE**		**MID**		**POST**		**|Effect Size|**		
	Group	**Mean ± SD**	**95% CI**	**Mean ± SD**	**95% CI**	**Mean ± SD**	**95% CI**	**1vs2**	**2vs3**	**1vs3**
5 m run (s)	TSG	2.5 ± 0.3	2.4; 2.7	2.5 ± 0.4	2.3; 2.7	2.4 ± 0.3	2.3; 2.6	0.23	0.13	0.41
	STG	2.5 ± 0.2	2.4; 2.6	2.4 ± 0.2	2.3; 2.5	2.4 ± 0.2	2.3; 2.5	0.32	0.10	0.39
	CON	2.6 ± 0.4	2.3; 2.9	2.5 ± 0.3	2.3; 2.8	2.5 ± 0.3	2.3; 2.7	0.22	0.03	0.26
Crawl (s)	TSG	8.0 ± 2.0	7.0; 9.1	6.7 ± 1.8 ***	5.8; 7.7	6.4 ± 1.3 ***	5.7; 7.1	0.69	0.22	0.96
	STG	7.5 ± 1.4	6.8; 8.3	6.5 ± 1.2 **	5.8; 7.2	6.4 ± 1.7 **	5.4; 7.4	0.81	0.05	0.74
	CON	7.3 ± 1.0	6.5; 8.0	6.6 ± 1.8	5.4; 7.9	6.6 ± 1.8	5.3; 7.8	0.47	0.05	0.53
KB carry (s)	TSG	12.0 ± 1.9	11.0; 12.9	11.0 ± 1.7 ***	10.1; 11.8	11.1 ± 1.8 *	10.2; 12.0	0.58	0.08	0.50
	STG	11.5 ± 1.2	10.8; 12.1	10.8 ± 1.1 *	10.2; 11.4	10.9 ± 1.4	10.1; 11.7	0.61	0.07	0.47
	CON	11.5 ± 1.3	10.6; 12.4	11.2 ± 1.4	10.2; 12.2	11.2 ± 1.3	10.2; 12.1	0.22	0.04	0.26
Drag (s)	TSG	11.7 ± 3.7	9.8; 13.6	9.8 ± 2.4 ***	8.6; 11.1	9.7 ± 2.3 ***	8.5; 10.9	0.61	0.04	0.65
	STG	10.6 ± 2.4	9.3; 12.0	9.2 ± 1.6 **	8.4; 10.1	9.6 ± 1.9 *	8.5; 10.7	0.72	0.11	0.49
	CON	10.7 ± 2.0	9.3; 12.1	10.6 ± 3.2	8.3; 12.9	10.5 ± 2.9	8.4; 12.5	0.04	0.05	0.11
10 m run (s)	TSG	3.1 ± 0.4	2.9; 3.4	3.0 ± 0.4 *	2.8; 3.1	2.9 ± 0.3 *	2.8; 3.1	0.54	0.03	0.64
	STG	3.1 ± 0.4	2.9; 3.4	2.9 ± 0.3 ***	2.7; 3.0	2.9 ± 0.3 *	2.7; 3.0	0.74	0.18	0.72
	CON	3.1 ± 0.5	2.7; 3.4	3.0 ± 0.5	2.6; 3.4	3.0 ± 0.6	2.6; 3.4	0.14	0.04	0.10

TSG = task specific training group; STG = strength training group; CON = control group; * = compared to PRE values * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

TABLE 16 Simulated military task performance times for different tasks (first 5 m run, crawl, kettlebell carry (KB), casualty drag, and final 10 m run) from the second trial in the PRE, MID, and POST measurement points. PRE – MID 6 weeks, PRE – POST 12 weeks, MID – POST 6 weeks

Second Trial		PRE		MID		POST		|Effect Size|		
	Group	Mean ± SD	95% CI	Mean ± SD	95% CI	Mean ± SD	95% CI	1vs2	2vs3	1vs3
5 m run (s)	TSG	2.6 ± 0.4	2.4; 2.8	2.5 ± 0.3	2.3; 2.6	2.5 ± 0.3 *	2.3; 2.6	0.24	0.21	0.21
	STG	2.6 ± 0.2	2.4; 2.7	2.5 ± 0.2	2.4; 2.7	2.4 ± 0.2	2.3; 2.6	0.10	0.43	0.55
	CON	2.8 ± 0.2	2.7; 3.0	2.6 ± 0.5	2.3; 3.0	2.6 ± 0.4 *	2.4; 2.9	0.60	0.05	0.68
Crawl (s)	TSG	9.7 ± 2.9	8.2; 11.2	7.7 ± 2.0 ***	6.7; 8.7	7.1 ± 1.5 ***, ##	6.3; 7.9	0.81	0.37	1.12
	STG	8.9 ± 1.9	7.8; 9.9	7.7 ± 1.5 *	6.9; 8.6	7.5 ± 1.9 ***	6.4; 8.5	0.69	0.16	0.77
	CON	8.4 ± 1.7	7.2; 9.7	7.8 ± 2.2	6.2; 9.4	7.1 ± 1.8 **, #	5.9; 8.4	0.33	0.35	0.78
KB carry (s)	TSG	14.1 ± 3.4	12,4; 15.8	12.3 ± 1.9 **	11.4; 13.3	11.9 ± 1.8 ***, #	11.0; 12.8	0.68	0.23	0.85
	STG	13.0 ± 1.5	12.2; 13.8	11.9 ± 1.1 ***	11.2; 12.5	11.6 ± 1.2 ***	10.9; 12.3	0.90	0.22	1.06
	CON	13.0 ± 2.0	11.6; 14.4	12.7 ± 2.1	11.2; 14.2	11.7 ± 1.6 **, ###	10.6; 12.8	0.33	0.58	0.79
Drag (s)	TSG	14.2 ± 5.2	11.5; 16.9	11.5 ± 3.0 ***	9.9; 13.0	11.2 ± 2.8 ***	9.7; 12.6	0.66	0.10	0.74
	STG	13.6 ± 4.2	11.3; 15.9	10.9 ± 1.9 **	9.9; 12.0	10.8 ± 2.6 ***	9.3; 12.3	0.85	0.06	0.83
	CON	13.4 ± 2.9	11.3; 15.4	12.3 ± 3.8	9.7; 15.0	11.3 ± 3.5	8.8; 13.8	0.32	0.30	0.67
10 m run (s)	TSG	3.5 ± 0.6	3.2; 3.8	3.2 ± 0.4 *	3.0; 3.4	3.3 ± 0.4 *	3.1; 3.4	0.59	0.06	0.54
	STG	3.6 ± 0.4	3.3; 3.8	3.1 ± 0.3 ***	2.9; 3.3	3.1 ± 0.3 ***	3.0; 3.3	1.12	0.25	1.28
	CON	3.5 ± 4.0	3.2; 3.8	3.4 ± 0.7	2.8; 3.9	3.2 ± 0.5*	2.8; 3.5	0.30	0.26	0.78

TSG = task specific training group; STG = strength training group; CON = control group; * = compared to PRE values * = p < 0.05, ** = p < 0.01, *** = p < 0.001; # = compared to MID values # = p < 0.05, ## = p < 0.01, ### < 0.001.

TABLE 17 Simulated military task performance times for different tasks (first 5 m run, crawl, kettlebell carry (KB), casualty drag, and final 10 m run) from the third trial in the PRE, MID, and POST measurement points. PRE – MID 6 weeks, PRE – POST 12 weeks, MID – POST 6 weeks.

Third Trial		**PRE**		**MID**		**POST**		**|Effect Size|**		
	Group	**Mean ± SD**	**95% CI**	**Mean ± SD**	**95% CI**	**Mean ± SD**	**95% CI**	**1v2**	**2v3**	**1v3**
5 m run (s)	TSG	2.9 ± 0.6	2.6; 3.2	2.6 ± 0.3 ***	2.4; 2.8	2.6 ± 0.3 ***	2.4; 2.7	0.70	0.16	0.81
	STG	2.8 ± 0.3	2.6; 2.9	2.6 ± 0.2 **	2.5; 2.7	2.6 ± 0.3 *	2.4; 2.7	0.81	0.04	0.78
	CON	2.8 ± 0.5	2.5; 3.2	2.9 ± 0.7	2.5; 3.4	2.7 ± 0.5 ##	2.4; 3.0	0.22	0.43	0.25
Crawl (s)	TSG	11.2 ± 3.6	9.4; 13.1	8.9 ± 2.3 ***	7.7; 10.1	7.9 ± 1.8 ***, ##	7.0; 8.9	0.80	0.47	1.19
	STG	10.6 ± 2.6	9.2; 12.1	8.5 ± 2.0 ***	7.4; 9.6	8.0 ± 1.6 ***	7.1; 8.8	0.93	0.30	1.26
	CON	9.0 ± 1.5	7.9; 10.1	9.2 ± 3.3	6.9; 11.6	7.4 ± 1.9 *, #	6.0; 8.8	0.08	0.71	0.99
KB carry (s)	TSG	15.4 ± 3.8	13.4; 17.3	13.4 ± 2.2 ***	12.2; 14.5	12.9 ± 2.7 ***	11.5; 14.3	0.67	0.20	0.79
	STG	14.0 ± 1.9	13.0; 15:0	12.6 ± 1.5 **	11.8; 13.4	11.9 ± 1.4 ***, ##	11.1; 12.7	0.86	0.46	1.28
	CON	13.6 ± 1.7	12.4; 14.8	13.5 ± 2.4	11.8; 15.2	11.8 ± 1.9 **, ###	10.4; 13.1	0.08	0.84	1.09
Drag (s)	TSG	15.9 ± 5.8	12.9; 18.9	13.0 ± 3.1 **	11.4; 14.6	11.9 ± 2.6 ***, #	10.6; 13.2	0.64	0.40	0.92
	STG	15.6 ± 5.6	12.5; 18.7	12.1 ± 3.4 ***	10.2; 14.0	11.9 ± 4.1 ***	9.6; 14.2	0.77	0.07	0.78
	CON	13.8 ± 2.9	11.7; 15.9	13.2 ± 3.8	10.4; 15.9	12.4 ± 3.3	10.0; 14.8	0.20	0.22	0.47
10 m run (s)	TSG	3.8 ± 0.6	3.5; 4.1	3.4 ± 0.3 **	3.2; 3.6	3.4 ± 0.4 *	3.2; 3.6	0.84	0.06	0.72
	STG	3.5 ± 0.3	3.3; 3.7	3.3 ± 0.5	3.0; 3.6	3.2 ± 0.4 *	3.0; 3.4	0.40	0.25	0.83
	CON	3.6 ± 0.5	3.2; 4.0	3.7 ± 0.7	3.1; 4.2	3.5 ± 0.8	2.9; 4.0	0.12	0.26	0.18

TSG = task specific training group; STG = strength training group; CON = control group; * = compared to PRE values * = p < 0.05, ** = p < 0.01, *** = p < 0.001; # = compared to MID values # = p < 0.05, ## = p < 0.01, ### < 0.001

5.2.5 Associations between body composition, physical tests, and simulated military task

Absolute individual changes in physical tests and times in the simulated military task performance had significant negative correlations with the PRE ($r = -0.366$ to -0.659, $p < 0.05$), MID ($r = -0.352$ to -0.789), and POST ($r = -0.338$ to -0.725) measurements. Furthermore, absolute individual changes in physical performance and individual changes in the simulated military task performance, significantly correlated with the PRE–MID measurements in isometric leg press force (second trial; $r = -0.396$, $p = 0.009$) and in maximal power (first trial; $r = -0.348$, $p = 0.026$). Similar correlations were found between the PRE–POST measurements in leg strength (second trial; $r = -0.333$, $p = 0.031$), maximal power (first trial; $r = -0.429$, $p = 0.005$), and CMJ (first trial; $r = -0.451$, $p = 0.003$). In the MID and POST measurements, no significant correlations between the changes in different tasks were found.

When looking at the relative change in time in the PRE–MID time points compared to absolute PRE times, there were significant negative correlations in STG ($r = -0.669$, $p = 0.003$) and TSG ($r = -0.666$, $p = 0.007$) in the second trial and in STG ($r = -0.766$, $p = 0.000$) in the third trial. In the CON group, no significant correlations were found (Figure 5).

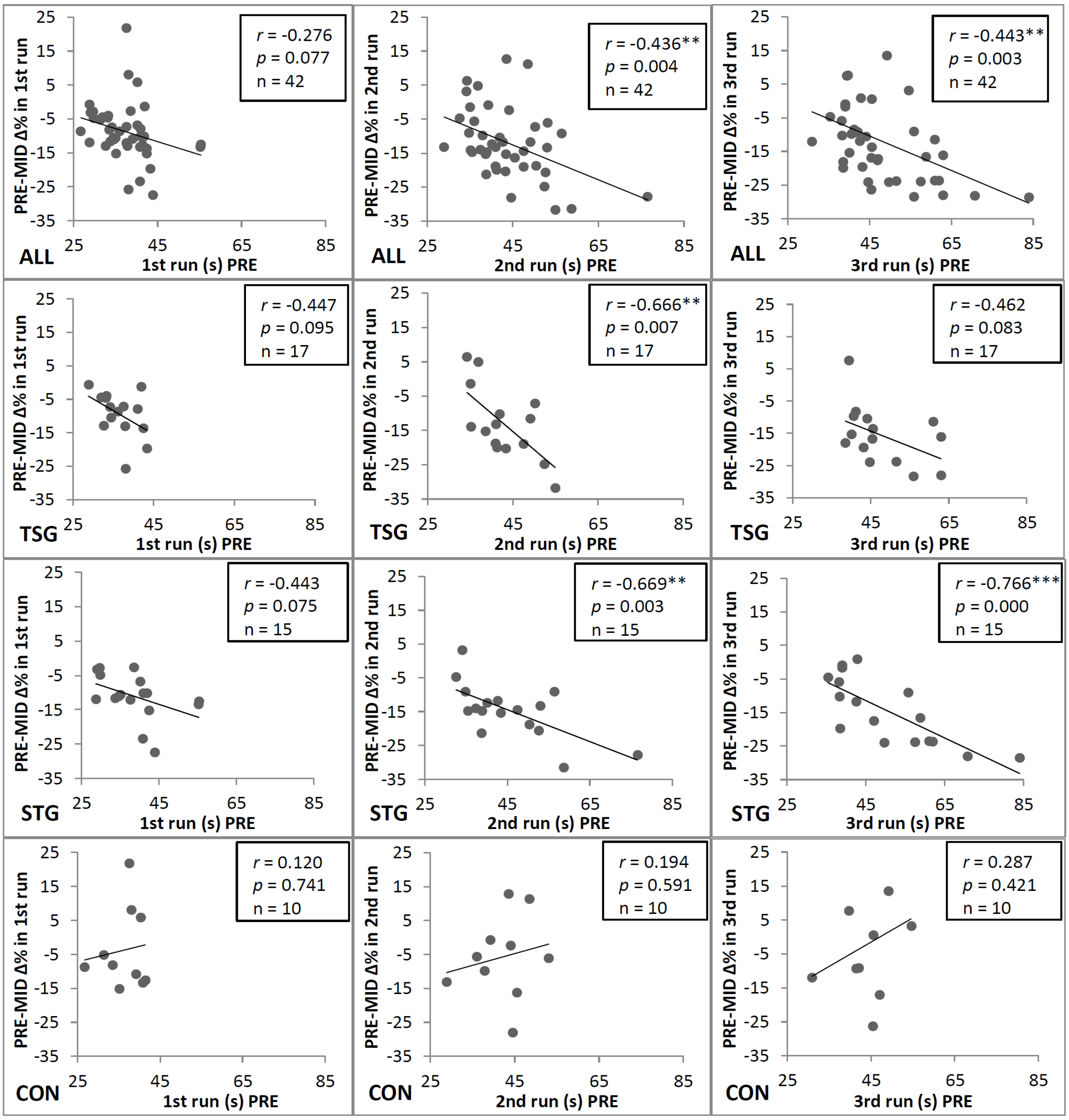

FIGURE 5 Correlations between absolute time in the 1st, 2nd, and 3rd run and the PRE–MID change (%) in time. ALL = all subjects; TSG = task specific training group; STG = strength training group; CON = control group; * = p < 0.05, ** = p < 0.01, *** = p < 0.001. PRE – MID 6 weeks, PRE – POST 12 weeks, MID – POST 6 weeks.

6 DISCUSSION

6.1 Physiological responses to military field training

The present studies support the previous military field training studies, and add new findings to the existing literature on stressors as well as key military physiological performance measures. In the first study, reduction in physical performance, changes in physical activity and body composition were found during the 21-day MFT. All measured body composition variables (BM, SMM and FM) declined during the 21-day MFT, but the values appeared to recover after four days of rest to the PRE value level. In previous studies (Alemany et al. 2008; Chester et al. 2013; Kyröläinen et al. 2008; Nindl et al. 2002) a decline in body mass, fat free mass and fat mass after a short-term (less than 14 days) MFT was also observed. Furthermore, 8 weeks of strenuous military training appears to cause drastic declines in soldiers body composition (Nindl et al. 2002; Richmond et al. 2014; Sporis et al. 2012).

The main reason for the changes in body composition in previous studies has been energy deficit (Alemany et al. 2008; Kyröläinen et al. 2008). The occupational tasks a soldier has to perform during MFT require more energy than they consume from their daily meals. Strenuous MFT might lead to decreased body mass, not only through loss of fat mass, but also of fat free mass. Because of this, it is important to have a sufficient recovery period between MFT and possible deployment.

During the first study, the soldiers had three meals during a day. The meals were prepared by the maintenance corps in the field and the quantity of calories were 3300–3500 kcal per day. The activity measurements showed that there were some less active recovery days during the 21-day MFT and because of that, the energy deficit was not present throughout. This probably explains why the changes in body composition were not as drastic as seen in previous studies.

The first study also demonstrated decrements in physical performance in soldiers during the 21-day MFT. Muscle endurance performance declined in both sit-ups and push-ups. The decline was found during different measurement points: in the MID measurements for sit-ups and in the POST measurements for push-ups. Earlier, Rintamäki et al. (2012) have reported a decline in muscle endurance after MFT. The different results in sit-ups and push-ups observed might be influenced by the occupational tasks the soldiers performed within the MFT. During the ST phase, they were not carrying heavy loads and marching long distances. In previous studies, load carriage performance has been shown to be linked to improvement in upper body strength (Knapik et al. 2007). In addition, in previous MFT studies, muscular endurance has similarly stayed the same or declined (Nindl et al. 2002, 2007). The observed decline in muscular endurance can partly be explained by the motivation of the soldiers to perform these tests, although they were verbally encouraged to perform their maximum effort in all measurement points. Also accumulated load carriage, living outdoors for three weeks and continued energy deficit might have influenced their ability to reach the PRE values in sit-ups and push-ups.

When looking at the lower body explosive strength (standing long jump) a significant decline was observed at all measurement points. In previous studies of Chester et al. (2013) and Nindl et al. (2007), a decline in lower body explosive strength was measured by vertical jump after MFT. Neuromuscular performance, as measured using standing long jump, seems to be negatively affected by long and high-volume physical activity. During a long MFT, the high volume of walking and load carriage tasks are related to a decline in lower body explosive strength and neuromuscular function. Load carriage has been reported to increase ground reaction force (Wang et al. 2012) and might ultimately cause a decline in neuromuscular function during a long MFT. Similar observations have been reported in vertical jump during strenuous special force courses (Nindl et al. 2007; Sporis et al. 2012). These declines in the neuromuscular function might be due to neural overtraining, decreased intramuscular viscoelastic properties, and incidence of muscle microtrauma. (Chalchat et al. 2020; Cormie et al. 2011; Hartmann et al. 2015)

Regarding aerobic performance, no significant change was observed in 3.2 km loaded march time, although some individuals showed declines in their performance. The present MFT was not physically as demanding as previously reported courses (Nindl et al. 2007; Richmond et al. 2014). Previous studies (Mikkola et al. 2012; Santtila et al. 2008; Sporis et al. 2012) have also shown a small decline or no change during MFT in aerobic performance. When looking at the results, it seems that the neuromuscular capacity in the soldiers was overloaded during the MFT. After the MFT, four days of recovery time did not seem to be enough to return to PRE values. In the past, greater declines in the physical performance values were observed, when the MFT has been more intensive and demanding. Comparing the present findings with previous studies, the combined data suggests that the longer and more intensive MFT is, the more important it is to have sufficient recovery time to regain combat readiness. It is also important for soldiers to have appropriate physical fitness before MFT or deployment.

Maximal upper body strength increased significantly from the PRE to MID measurements but decreased back to the PRE levels in the POST and RECO measurements. This indicated that upper body strength was not affected by prolonged MFT. In leg extension, minor non-significant decreases were observed in the MID measurements. In the present study, it was also observed that the change in lower body strength positively correlated with the change in standing shooting score. A similar correlation was observed between the change in upper body strength and the change in standing shooting only between the PRE and RECO measurements. In previous studies, it has been shown that lower body strength is an important factor for soldiers to successfully fulfill their duties (Welsh et al. 2008; Kraemer & Szivak 2012). It appears that especially the lower body muscular strength seems to be an important factor for standing shooting accuracy for soldiers during MFT. In addition, both lower and upper body strength appear to be important for enhancing the recovery process as well as the accuracy of standing shooting during the recovery phase.

In the present study, a minor non-significant decrease in leg extension values was observed in the MID measurements but this decrease was not observed in the POST measurements. The reason for this may have been that the four days before the MID measurements were the most physically demanding part of the MFT. Kyröläinen et al. (2008) reported similar findings with reduced load during prolonged MFT, which indicates a lighter period in the middle of MFT, may allow strength and hormone levels to recover during MFT.

The average daily step count of physically healthy adults measured using electronic pedometers has been reported to be 7000–8000 steps per day (Knapik et al. 2007). In the present study, accelerometers and different algorithms enabled us to also measure running steps and the level of activity in METs during MFT, which pedometers could not record.

During the 21-day MFT, objectively measured physical activity was significantly higher than in the PRE measurement before MFT. When comparing the MFT and PRE measurements, the amount of light and moderate physical activity was two times greater during MFT than in the PRE measurements. The soldiers also took almost 50 % more steps during MFT. The total number of steps taken during MFT was, on average, 13937 ± 2276 steps per day, which can be classified as highly active, when compared to healthy adults (Tudor-Locke et al. 2008; Tudor-Locke et al. 2010). In a study by Schulze at al. (2015) with German Army soldiers, it was reported that the junior enlisted soldiers reached over 10000 steps in a day, while non-commissioned officers and officers did not reach 10000 steps per day. Schulze at al. (2016) also found that the average step count during work and leisure time among German soldiers was 8500 steps during a day and that only 41 soldiers out of 169 reached the recommend active step number of 10000 steps per day. In a study by Rintamäki et al. (2012), it was reported that soldiers took on average 5797 steps during a 12-hour work shift during a peacekeeping operation in Chad. Norwegian Home Guard troops did not increase their average step count (10500 steps per day) during military training when compared to civilian life (Aanstadt et al. 2016). It was also observed that the average VPA during military training was significantly lower than during civilian life, and there was more MPA during military training compared to civilian life.

During the US Army Basic Combat Training (BCT), Knapik et al. (2007) have studied physical activity with electronic pedometers. They have found that trainees performed an average of 16311 ± 5826 steps per day. During MFT, the highest daily average was 22372 ± 12517 steps per day. In our study, the highest daily average was 19724 ± 4169 steps per day. Overall, our activity results were lower when compared to the data by Knapik et al. (2007) but clearly higher than the reported results of Schultze et al. (2015, 2016) and Aanstadt et al. (2016).

Vincent et al. (2016) have studied activity as a level of MET and have found that firefighters performed an average of 7:33:00 hours of light activity, 2:36:00 hours of moderate activity and 0:01:00 hours of vigorous activity during a work shift. In addition, Chappel et al. (2016) have reported similar findings with firefighters, as they observed 7:10:00 hours of LPA, 2:32:00 hours of MPA and 0:00:02 hours of VPA during a work shift. In a study by Simpson et al. (2013), it was found that during the US Army BCT, the recruits on average performed 7:25:30 hours of sedentary activity, 2:20:30 hours of light activity (> 3.0 MET), 1:32:00 of moderate activity (3.0 – 6.0 MET) and 0:38:00 hours of vigorous (> 6.0 MET) activity during a normal training day. In a study with Swiss conscripts, Wyss et al. (2012) found that the conscripts engaged in LPA for 7:33:00 to 8:40:00, MPA for 3:45:00 to 5:46:00 and VPA for 0:05:00 to 0:16:00 h:min:s during a normal training day. They also found that the distance covered per day was greater than during the US Army BCT (Knapik et al. 2007) (15.6 km per day vs. 11.7 km per day).

In the present study, it was found that the average MPA performed during ST was 2:12:00 hours and during MFT was 2:48:00 hours. These results are similar to the data by Vincent et al. (2016) and Chappel et al. (2016) with firefighters MPA during their normal work shift, and more than in the study by Simpson et al. (2013) with the recruits of the US Army BCT, but less than during the Swiss conscripts (Wyss et al. 2012) training. When looking at all of these studies, it can be seen that there was only a couple of minutes of VPA during the measured days, and almost all of the activity was of either light or moderate intensity.

6.2 Neuromuscular adaptations during different physical training programs

In the second study, the objective was to observe how different physical training programs affect strength and power performances during the 12-week training period in soldiers. The subjects were divided into three training groups of equal training volume; however, the content of the training varied between the groups. Both the strength and task specific training programs improved maximal strength and power variables to a greater degree compared to normal military physical training. These findings are in line with previous findings (Friedl et al. 2015; Kraemer & Szivak 2012) that soldiers need high levels of strength and power related training combined with cardiovascular training. With the high amounts of physical activity during a normal military training day, it is clear that daily military activities might have an impact on the development of different physical characteristics. In the present study, physical training was compromised by MFT in the latter part of the 12-week training period, but was still enough to maintain fitness levels.

An earlier study with conscripts (Santtila et al. 2008) has reported that basic military training can lead to increases in different components of physical performance including both endurance and strength. Hendrickson et al. (2010) and Knapik et al. (2001) have reported similar results during U.S. Army Basic Training. Development of power and strength variables in previously trained soldiers has been reported in different studies (Abt et al. 2016; Lester et al. 2014; Solberg et al. 2015). In the present study, the TSG and STG groups showed the highest increase in the strength and power measurements both between the PRE and MID and PRE and POST measurement points. It is important to note that the training was not compromised by MFT during the first 6 weeks of the study as it was during the last six weeks of the study. The total number of training sessions during the whole study was 18. The first six weeks included 12 training sessions and the last six weeks only consisted of 6 training sessions. Therefore, the first six weeks was the actual training intervention period, while the last six weeks were the maintenance period. During the first part, there was only one five-day MFT; however, during the second part, the schedule had four five-day MFTs. This meant that the amount of training ranged from 2–3 sessions per week during the first part compared to 0–2 sessions during the second part of the study. There was a clear plateau in strength and power observed between the MID and POST measurement points, which was likely due to the decreased amount of controlled training and the increased amount of MFT. Most of the improvement in the measured variables was found in the first six weeks of the study when the amount of training sessions per week was 2–3. During the last part of the study, the low volume of training sessions (0–2) per week was not enough to induce changes in strength and power, but it was enough to maintain the level that was reached during the first 6 weeks of the study. Previously, 2 - 3 strength training sessions have been reported to lead to increases in strength performance, while less than two may instead decrease strength results (Graves et al. 1988). It is important to point out that the present CON group also showed improvements in strength and power variables, but not to the same degree as in the TSG and STG groups during the study. In earlier studies in the military environment (Santtila et al. 2008; Vaara et al. 2015), it has been shown that more than two sessions per week should be performed to produce improvements in strength and power performance. In addition, the slightly higher amount of endurance training in the CON group may have interfered with the strength and power gains compared to STG and TSG. Unfortunately, due to the study design, it was not possible to evaluate changes in maximal aerobic performance between the groups. One reason for the gains in STG and TSG was the increased training stimuli for the upper and lower body muscles, which the CON group did not have.

When looking at the results from the different training programs, it must be remembered that the study was conducted during normal military service. During the present study, the conscripts were completing their military service, which involves a high volume of low aerobic type of activity with constant load carriage. This type of activity is unavoidable, because of the tactical and physical demands of military training. The pioneer study by Hickson (1980) showed that strength development, but not endurance, might be compromised when a high frequency of intensive running and strength training were performed concurrently for more than 6–8 weeks. Since then, it has been found that training on alternative days compared to training both endurance and strength in the same day, might be more beneficial for both aerobic and strength development (Coffey & Hawley 2017). The normal daily military training schedule did not allow time for rest periods after physical training sessions or MFT. It is likely that our concurrent training protocol had an effect on the physical performance of the subjects (Häkkinen et al. 2003; Schumann et al. 2015). In the present study, the goal was to find out what kind of training would be most beneficial during normal military service. In addition, as mentioned earlier, MFT might have impacted the training responses during the last 6 weeks of training. To conclude, the STG and TSG training led to greater development of strength and power than the training of the CON group. Lower and upper body strength as well as lower body power improvements were greater in STG and TSG compared to the CON group. It is important to note that normal daily military training might contain a high amount of low-intensity aerobic work, which could influence the development of strength and power production in soldiers.

It is important that soldiers have reached an appropriate physical performance level before deployment or MFT, and a sufficient recovery period is given after a long military training course or MFT to return to combat readiness again following training (Conkright et al. 2020). MFTs and deployments create a complicated environment for strength development considering endurance training is fully integrated into soldiers' daily activities and training. In the literature, it has been shown that high (> 3 times per week) endurance training frequency, with high training volumes, might have a negative influence on strength and power performance during concurrent training (Coffey & Hawley 2017; Hickson et al. 1980; Häkkinen et al. 2003; Schumann et al. 2014; Wilson et al. 2012). It is likely that daily military activities have a similar effect on the development of strength and power characteristics.

No significant changes were found in the physical performance tests between the training groups at all measurement points. In the maximal six-second cycling test, maximal power increased in all groups, but TSG and STG improved more between the PRE and MID measurements. In the maximal isometric strength test, the only significant improvements were observed in leg press in the TSG and in bench press in the STG. In CMJ, only small significant improvements were observed in the TSG and STG. Despite the fact that no significant differences between the groups were found in the present study, greater improvements took place in the TSG and STG in the strength and power tests compared to the CON group. In addition, the improvements were similar throughout the study in the TSG and STG. Task-specific training seems to be as effective as strength training to improve soldiers' military occupational specific performance. Harman et al. (2008) presented similar findings in a study also done in the military environment.

TSG and STG both improved in the simulated military task course more than the CON group, especially in the first 6 weeks of the study. When looking at the results in more depth, TSG showed greater improvements in most of the tasks performed during the course compared to STG. This is likely due to specific training with the same tasks as the actual simulated course in TSG (Gamble et al. 2006). All the groups had similar drills during their regular military training, with lower volume and intensity. This learning effect was observed in all groups as the time to complete the military task course improved with number of attempts. Harman et al. (2008) reported similar results that high-intensity task-specific training leads to improvements in military physical performance. The present improvements observed during the simulated course could be explained by increased aerobic capacity, which could not be measured reliably in the present study. A similar type of high-intensity interval training as was performed by TSG has been shown to lead to improvements in both aerobic and anaerobic performance (Gibala et al. 2015). When looking at the results, there is also a possibility that the military task-specific training, performed by TSG, could have had a greater effect on both aerobic and anaerobic performance than normal strength-based training. It is important to point out that the improvement in the casualty drag, which involves moving a heavy load as fast as possible, was significant in both TSG and STG, but no significant improvements were found in the CON group. The most likely reason for this was that the training of the CON group did not include any maximal or power type of training. Previous studies (Kraemer & Svizak, 2012; Mala et al. 2015) have shown that the ability to produce force and power is crucial for soldiers to improve their performance in tasks that require high amounts of strength or power. It is important to note that if the casualty drag would have been longer in time, even larger differences between TSG and STG compared to CON group might have been observed. Likewise, some indicators from the results point to the specificity of training principle; for instance, the STG improvements in isometric bench press and TSG improvements in maximal isometric leg press force during the first 6 weeks. The reason for these differences was most likely that the main focus in the TSG was on lower body training, while STG also performed upper body exercises. It is important to remember this when planning training programs for soldiers in the future. Kraemer et al. (2004) and Knapik et al. (2012) have shown that upper body maximal strength is important for soldiers' occupational performance. This is crucial to remember, especially, when designing training programs combined with field-based training.

In the second study, there was a strong correlation between the CMJ and six-second cycling power tests as compared to improved performance in the simulated military task course. Similar results have been reported in earlier studies when comparing power production and different task specific courses (Harman et al. 2008; Mala et al. 2015; Treloar et al. 2011). There was also a significant correlation between time to complete the first five meters run during the simulated military task and maximal upper body strength and push-up tests. This was similar to findings of Mala et al. (2015). This may be explained by the type of task, which was performed starting in the prone position followed by standing up to run. In this type of movement, there is a high involvement of the upper body extensors, which may be an important factor for performing the actual task (Treloar et al. 2011). In addition, increased fat-free mass correlated significantly with the improvement in the simulated military task performance and with the increase in maximal isometric strength. This has been shown in earlier studies by Mala et al. (2015) and Treloar et al. (2011) to be an important factor in evacuation type of tasks that involve high loads. When looking at the PRE measurements for the military task course and relative changes in time between the PRE and MID measurements, there was a significant correlation between the PRE time and the magnitude of improvement in TSG and STG. It seemed that both task-specific and strength training programs were highly effective for the subjects who did not perform well in the PRE measurements. Normal military physical training performed by the CON group did not show the same effect.

6.3 Serum hormone concentrations

6.3.1 Military field training

In previous studies, the circulating levels of IGF-1 haves been shown to have a positive relationship with aerobic fitness (Nindl et al. 2011). Other biomarkers (e.g., COR, TES, SHBG) have been shown to predict excessive rates of physical performance change. Furthermore, certain biomarkers that are sensitive to changes in homeostasis may serve as early indicators of stress or overreaching (Kyröläinen et al. 2008; Nindl et al. 2003; Tanskanen et al. 2011). As seen in the first study, the serum COR and SHBG concentrations increased from PRE to MID and POST. SHBG increased in the RECO measurements, but COR did not change. The serum TES and IGF-1 concentrations decreased during MFT and increased in the RECO measurements. We observed a positive correlation between the changes in serum cortisol concentrations and changes in standing shooting score. As reported in previous military field exercise studies (Chester et al. 2013; Nindl et al. 2002, 2007; Sporis et al. 2012), prolonged physical activity and the negative energy balance combined with sleep deprivation can have a negative impact on soldiers' hormonal balance and neuromuscular performance.

During the prolonged military field training, the serum TES concentration decreased significantly from the PRE to MID (–25%) and PRE to POST (–13%) measurements. In previous studies, similar findings have been reported (Alemany et al. 2008; Friedl et al. 2000; Kyröläinen et al. 2008). Interestingly, a significant increase was observed in the serum TES concentration between the MID to POST (16%) and POST to RECO (24%) measurements. This may be explained by the amount of physical load during MFT, which was higher at the beginning of training. On the other hand, the serum COR concentration increased significantly during MFT (31%) and did not return to resting levels during the recovery period (28%). Friedl et al. (2000) and Nindl et al. (2007) have observed similar findings with US Army Rangers during MFT. Kyröläinen et al. (2008) reported an increase (32%) in cortisol levels during a 20-day MFT. COR, unlike TES, showed no recovery after the MID measurements. This is an indicator that although the total loading of MFT was reduced towards its latter part, the stress levels were at their highest at the end of MFT, when soldiers training activity reached its capstone.

There was a significant increase in the SHBG values from the PRE to MID (9%) and to POST (14%) measurement points, but the values returned to the PRE values in the RECO measurements. Overall, these findings are in accordance with findings previously reported by McCauley et al. (2009), who have shown that the SHBG concentration has increased during strenuous physical training and with the findings of Alemany et al. (2008) and Tanskanen et al. (2011), where the SHBG values were elevated during military training and MFT.

MFT caused the IGF-1 concentration to decrease from the PRE to MID measurements by 20%. There was no change in the values between the MID to POST measurements. A return to the resting levels was observed in the RECO measurements. These results are in line with previous studies wherein similar findings have been reported (Nindl et al. 2002; Rosendahl et al. 2002; Vaara et al. 2015). However, even changes that are more drastic (–62%) have been found during special force training (Nindl et al. 2007). Friedl et al. (2000) have reported that the decrease in IGF-1 concentration is mainly due to physical strain and energy deficit, which has also been shown to decrease IGF-1 concentration. This decrease indicates that soldiers' ability to recover from physical strain and to repair muscle damage is weakened, which may lead to decreases in physical performance. These findings are consistent with research showing that IGF-1 concentration appears to be a good marker for evaluating soldiers' physical performance and recovery (Nindl et al. 2007).

When looking at the occupational skills of a soldier, previous studies regarding shooting performance in soldiers have primarily been measured after different simulations of military work. These studies have shown that high anaerobic work periods can decrease shooting accuracy, but shooting ability recovers quickly (Tenan et al. 2017). In a study by Evans et al. (2003), a fatiguing upper body obstacle course decreased shooting accuracy significantly, but it seemed to recover quickly. Another factor that has also been shown to decrease shooting accuracy is load carriage (Knapik et al. 1997), even though there seems to be no change before the carried loads reach at least of 45% of a soldiers' body weight (Nibbeling et al. 2014). Tenan et al. (2017) studied shooting performance in the field during a loaded march with live-fire shooting. Their study showed that load carriage and marching did not affect shooting accuracy, but the shooting actually improved with lighter load. The present findings revealed, however, that shooting from the prone position was not altered during MFT. Standing shooting was more sensitive to fatigue, but it seemed to decrease only after the most physically demanding part of MFT. Other studies (Nindl et al. 2002; Nindl et al. 2007) have shown declines in lower body strength and hormonal concentrations during MFT. This may explain the decline in the standing shooting score, because as physical exhaustion causes the heart rate to elevate, it can influence the shooting mechanisms (Tenan et al. 2017). Therefore, it is important in the future to investigate the interaction and differences between physiological and mechanical factors in soldiers in standing and prone shooting positions.

In the RECO measurements, almost all the measured values recovered to the PRE measurement levels, except the serum COR concentration was significantly higher than in the PRE measurements. Also, body weight (BW) and skeletal muscle mass (SMM) were significantly lower than in the PRE measurements, but almost recovered to the PRE values. It appears that four days is adequate for the soldiers to recover from the physical strain of the present prolonged MFT.

6.3.2 The 12-week training intervention

As reported in earlier studies, decreases in serum hormonal concentrations have been reported as a response to physical exertion combined with energy and sleep deprivation (Alemany et al. 2008; Friedl et al. 2000; Kyröläinen et al. 2008; Nindl et al. 2007; Richmond et al. 2014). During the 12-week training intervention, the TES and IGF-1 levels were either slightly increased or unaltered. COR remained unchanged during the study, while SHBG seemed to increase to some extent. These findings suggest that the soldiers were not overtrained during the study period. The majority of the changes in the serum concentrations may indicate an improved anabolic state. Despite this, the increases in the measured strength and power performance appeared to be minor between the MID and POST measurements.

Previous studies have shown that the total TES concentration acutely increases after resistance exercise (Häkkinen & Pakarinen 1993; Kraemer & Ratamess 2005). Tremblay et al. (2004) reported that the acute elevation in TES was greater in strength-trained than in endurance-trained men. These findings suggest that strength training could have beneficial periodical (Häkkinen et al. 1985b; Häkkinen et al. 1987; Häkkinen et al. 1988) adaptations in TES. During the training intervention, the increases in TES were observed during the first six weeks, but not during the last six weeks. The increased amount of military training increased the amount of concurrent training and could have contributed to the present findings. There was a significant increase in SHBG in all the groups from PRE to MID in the present study but SHBG concentrations remained statistically unaltered between the MID to POST measurements. Similar acute increases have been found in SHBG concentrations, but not in resting values in longer-term studies (Kraemer & Ratamess 2005). The COR concentrations decreased in all groups from the PRE to POST measurements. In previous studies, the COR concentrations have been shown to increase acutely, but no consistent pattern has been found in long-term training stress (Kraemer & Ratamess 2005). Resting serum IGF-1 concentration has been reported to be higher in resistance-trained than untrained men. Apparently, the volume and training intensity are important factors for chronic IGF-1 adaptations (Kraemer & Ratamess 2005). During the present study, the increases in IGF-1, as well as in IGFBP-3 concentrations, were observed only in the CON group and STG. It is possible that these findings indicate that a different order of military-type concurrent training can elevate anabolic hormone concentrations and contribute to an increase in muscle mass as observed in the present TSG and STG.

6.4 Methodological considerations and limitations

Upon reflection of the methodological considerations and limitations in the present study there are several points that need to be taken into account. The participants were representatives of a larger population who were performing their military service. The actual subjects in both studies represent only a small fraction of the total number of conscripts. This is important to remember when looking at the data and comparing it to the whole conscript population. In addition, the number of discontinued subjects might have influenced the results, because most of them belonged to the lower half in terms of physical fitness. This might also increase the overall motivational effect to perform the physical tests at the highest level, because the least motivated subjects were the ones who dropped out. In addition, some lack of motivation could be seen, especially, in the 3.2 km march during the PRE and POST measurements, which may have influenced the performance time, but only with a few subjects. In both studies, the bioelectrical impedance analysis was utilized to measure body composition changes, although it has been shown to overestimate body fat and muscle mass (Sillanpää et al. 2014) Because of the tight schedule of military field training it was the only possible way to measure body composition. Bioelectrical impedance analysis is based on fluid content of the body, changes in hydration status, particularly intramuscular water content, may interfere measured impedance and the results. During the actual measurements, one limitation was that the amount of sleep was not measured objectively. Sleep would have been important when discussing about recovery from MFT. In addition, within the subjects, there was some variation in the occupational tasks they performed which might have influenced their physical activity during the MFTs. Nevertheless, the variation of activity was not great, and there were only a few subjects that had different occupational tasks.

In both studies, the subjects were familiarized with the physical and occupational tests during their military service, but some new tests were implemented (maximal isometric tests), which could have had some influences on the results due to a learning effect. Despite this, the experienced researchers carefully controlled all the measurements, and the tests were completed in the same order and at the same time of day in all the measurement points. Additionally, the occupational movements and tasks were the same or very similar to the ones that the soldiers performed during their normal military training. In addition, during MFT, there was daily control of the subjects and the researchers were able to monitor them over the whole study period. In the first study, the actual MFT lasted for 21 days, which made it more realistic compared to short three to five days MFTs. Because the MFT was part of a larger military exercise, the physical loading in the last part of MFT was lower than expected. Because of this, it might have influenced the observed measures, as shooting and isometric maximal strength did not decline after the MID measurements as expected based on prior studies.

In the second study, there were a limited number of subjects per group, which might have reduced the generalizability of the findings. The training programs for STG and TSG were different from the traditionally performed physical training programs during the basic training period. The exercises performed were familiar for most of the subjects, but better familiarization might be needed in the future. In addition, an endurance-training group was planned to be included in the experimental design, but it was dropped out of the study, because of a low number of subjects. The endurance group with an occupational endurance test might have provided more information on the effectiveness of different training programs. In the future, it will be important to better periodized the military and physical training to achieve better enhancement of physical performance. It is important to note that future research should try to follow the development of strength and power throughout the military service. In this way, it would be easier to develop a more optimal long-term training program for strength and power in the military environment.

7 MAIN FINDINGS AND CONCLUSIONS

Overall, the first study of this thesis showed that there was significantly more physical activity during MFT than during a usual training week at the garrisons. During ST, there seemed to be more intensive physical activity, but not a higher total number of steps. The activities performed during ST are more of an anaerobic type, and the soldiers had more rest time during the nights. Physical activity during MFT was more of an aerobic type, and the total physical activity observed was divided into longer timeframes during a training day. Considering the higher level of physical activity during a prolonged MFT, there seems to be a greater energy deficit and larger decreases in BM, SMM and FM. Despite this, body composition values were observed to recover during a short-term recovery period after MFT. When looking at the physical performance tests, it can be concluded that the prolonged MFT had an adverse effect on strength levels and shooting ability in soldiers. Especially, muscle endurance seemed to decrease after MFT, and a similar observation was also made in lower body muscle power. No change was observed in 3.2 km march time, which indicates that aerobic performance stayed almost the same. Shooting from a prone position was not affected, while the changing loads and occupational tasks during MFT affected the shooting accuracy from the standing position. It is important to recognize that soldiers should shoot from a prone position, whenever possible, especially when fatigued. It is important to have a low physical intensity week after prolonged MFT to ensure that the soldiers receive an appropriate amount of rest, for advancing their recovery before fully returning to normal training.

The second study showed that both the task-specific and strength training programs were more effective than CON during the first six weeks of training in improving performance in different physical and occupational tests. During the second six weeks of the study, the subjects were able to maintain physical fitness and simulated military task course performance, despite the high amount of military field training and the decreased number of actual physical training sessions.

It is essentially important to periodize physical training to achieve the greatest improvements during military service and to have high-intensity training alongside with low-intensity military training to improve soldiers' occupational task specific performance. During an intensive strength-training period accompanied by military training, it is important to attempt to stimulate both acute and chronic positive hormonal changes as well as increased maximal strength and power of the trained muscles. Military task-specific training could be as effective as normal strength training to improve occupational repeated military task course time in soldiers. Without a doubt, this is an important finding, because this kind of training can be carried out without a high amount of equipment and in large groups compared to traditional gym-based strength training. In the military environment, an optimal combination for training should include high-intensity simulated military occupational task training and traditional strength focused gym training in consideration with the military training phase and available equipment. Furthermore, an intensive six-week strength and power-training period during specialized military training can improve physical and military occupational performance in previously trained soldiers. There is a need to compare different training programs over a longer follow-up period. Likewise, it looks like it is also possible to maintain physical and military occupational task performance levels during a six-week intensive military field-training period with only a few physical training sessions.

To achieve the best possible results, proper variation in the training content must be created during military training. By doing this, it is possible to make improvements to the soldiers' physical performance capacity, especially in strength and power variables, which can then be translated to improvements in common tactical movements (i.e., marching, load carriage and fire and movement drills). With regular, controlled, and structured physical training, the impact on physical performance in soldiers would be greater than with the current military physical training. On the other hand, the best strength and conditioning programs for soldiers cannot be built without taking into account the fractured nature of training caused by military occupational specific training requirements. The leadership should prioritize quality-controlled physical training in the future and support the necessary changes to physical training in soldiers. In other words, strength and occupational task specific training can lead to improvements in the battlefield performance, reduce the risk of overtraining, and prevent injuries caused by excessive running and loaded marching during the traditional military training. Additionally, in the future it will be important to study the effects of strength and occupational task specific training after the basic training period to optimize the training periodization, duration, intensity, and frequency in an attempt to develop the physical performance capacity required for the battlefield.

Finally, yet importantly, the daily physical training recommendations should take into account the general character of daily military training, including low-intensity and high-volume endurance training with an additional load of 25–65 kg. In consideration of that, progressively advancing combined strength, power, and endurance training, which includes a proportion of high intensity interval training, seems to generate superior adaptations in physical performance in soldiers. To create more effective enhancements in physical adaptations and performance, attention should move towards more progressive and individualized physical training programs, which are particularly divided into training phases that continuously aim to improve performance. Consequently, an individualized approach to human performance optimization should be taken when trying to improve physical fitness in soldiers and to reach better operational readiness.

YHTEENVETO (FINNISH SUMMARY)

Sotilaan kuormittuminen pitkäkestoisessa taisteluharjoituksessa sekä voima- ja kestävyysharjoittelun vaikutus fyysiseen toimintakykyyn ja kehon koostumukseen

Tämän tutkimuksen ensimmäisen vaiheen tavoitteena oli tuottaa uutta tietoa sotilaan fyysisistä vaatimuksista pitkäkestoisen taisteluharjoituksen aikana. Toisena päätarkoituksena oli tutkia fyysisen harjoittelun kehittämisestä varusmieskoulutuksen E- ja J-kausien aikana. Tutkimus pyrki selvittämään, minkälaista liikuntakoulutuksen tulisi olla parhaimpien mahdollisten tulosten saavuttamiseksi sotilaan fyysistä toimintakykyä mittaavissa fyysisissä testeissä.

Suorittaakseen tehtävänsä menestyksekkäästi sotilas tarvitsee hyvää fyysistä suorituskykyä ja maastossa liikkumisen taitoa. Varusmiespalveluksen aikana nuoren suomalaisen miehen fyysistä suorituskykyä pystytään parantamaan oikeanlaisella harjoittelulla eri sotilastehtävien vaatimusten mukaisesti. Oikein suunnitellulla, systemaattisesti jaksotetulla ja riittävän kuormittavalla liikuntakoulutuksella pystytään vaikuttamaan kehittävästi sotilaan fyysiseen toimintakykyyn eri sotilastehtävien vaatimusten mukaan.

Tämä tutkimus toteutettiin kahdessa vaiheessa. Ensimmäinen vaihe sisälsi 21 vuorokauden mittaisen maastoharjoituksen, jossa selvitettiin pitkäkestoisen taisteluharjoituksen vaikutuksia sotilaan fyysiseen toimintakykyyn. Toisen tutkimusvaiheen tavoitteena oli kartoittaa, miten eri tavoilla painotettu liikuntakoulutus vaikuttaa varusmiesten fyysisten ominaisuuksien kehittymiseen.

Sotilaiden fyysistä toimintakykyä ja sen kehitystä pyrittiin arvioimaan erilaisten fyysisten ja fysiologisten testien ja mittausten avulla. Näiden lisäksi varusmiesten stressitilaa, ravinnonsaantia, unen määrää, liikunta- ja terveyskäyttäytymistä sekä fyysistä harjoittelua seurattiin kyselyiden ja päiväkirjojen avulla.

Tutkimuksen ensimmäisessä vaiheessa havaittiin, että sotilaan työ on pitkäkestoista ja matalatehoista aerobista työtä, joka vaatii raskaidenkin taakkojen kantamista ja nostamista. Taisteluvaiheessa tarvitaan myös nopeutta ja anaerobista suorituskykyä. Koska sotilaan päivittäiset tehtävät sisältävät paljon matalatehoista työtä, on tärkeää, että liikuntakoulutuksessa pystyttäisiin antamaan erilaisia ärsykkeitä keholle. Tehokkain tapa parantaa koulutettavan sotilaan fyysistä toimintakykyä on harjoitella sekä kestävyys- että voimaominaisuuksia.

Toisessa vaiheessa toteutetun harjoittelututkimuksen tuloksena nähtiin, että sotilaan voimaharjoittelun tulee olla suunnitelmallista ja ohjattua. Sotilaiden kestävyyden taas on osoitettu kehittyvän tehokkaasti intervallityyppisellä harjoittelulla. Säännöllisen ja suunnitelmallisen voimaharjoittelun tiedetään olevan yhteydessä lihaksiston sekä sen tukiosien, jänteiden ja sidekudosten voiman kehittymiseen, tehon ja nopeuden lisääntymiseen ja motorisen suorituskyvyn paranemiseen. Voimaharjoittelusta on hyötyä myös taakankantokykyyn, mikä on tyypillinen sotilaan työtehtävä taistelukentällä.

Tutkimuksen tulosten perusteella voidaan todeta, että tehtäväkohtaiseen ja perinteiseen voimaharjoitteluun painottuneiden ryhmien välillä ei ollut eroja voimaominaisuuksien kehittymisessä, mutta kummassakin ryhmässä varusmiehet kehittyivät selvästi enemmän kuin nykyisen erikoiskoulutuskauden fyysistä harjoitusohjelmaa noudattaneet. Tutkimuksessa havaittiin, että harjoitusvaikutukset olivat suurimmat kuuden ensimmäisen viikon aikana, ja pienemmät kuuden jälkimmäisen viikon aikana, jolloin oli runsaasti useita maastoharjoituksia. Jatkossa on tärkeää tutkia tarkemmin tehtäväkohtaisen ja perinteisen voimaharjoittelun eroja koko varusmieskoulutuksen aikana.

Tulevaisuudessa olisi oleellista määrittää poikkeusolojen sotilaan tehtäväkohtaiset toimintakykyvaatimukset ja laatia niiden pohjalta eri tehtäviin fyysisen toimintakyvyn kehittämiseen ja ylläpitämiseen liittyvät harjoitusohjelmat. Harjoittelun ohjelmoinnissa tulisi painottaa yhdistettyä kestävyys- ja voimaharjoittelua, joiden perusteet tulisi kouluttaa jo varusmieskoulutuksen aikana ja tukea ominaisuuksien ylläpitoa reservissä. Ammattisotilaille olisi tarpeellista kehittää fyysisen toimintakyvyn mittaus- ja seurantamenetelmiä, joilla pystyttäisiin tehokkaasti testaamaan sotilaille tärkeitä ominaisuuksia ja antamaan näiden pohjalta kehittämiskohteita ja harjoitusohjelmia.

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ORIGINAL PAPERS

I

CHANGES IN PHYSICAL PERFORMANCE DURING 21 D OF MILITARY FIELD TRAINING

by

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Changes in Physical Performance During 21 d of Military Field Training in Warfighters

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ABSTRACT Introduction: Few studies have reported the amount of physical activity (PA) and its associations to physical performance of warfighters during military field training (MFT). The purpose of this study was to investigate changes in neuromuscular performance and PA among male Finnish Army conscripts during a 21-d MFT and to evaluate their recovery during 4 d after MFT. Methods: Body composition and physical performance were measured four times during the study (before MFT (PRE), after 12 d (MID), post training (POST) and after 4 d of recovery (RECO)). PA was measured throughout MFT in a group of healthy young male conscripts (n=49) by using a tri-axial accelerometer. The study was approved by the Finnish Defence Forces and was granted ethics approval by the Ethics Committee of the University of Jyväskylä. Results: Body mass declined significantly from 73.5 ± 8.7 to 71.6 ± 8.2 kg, but it recovered close to the PRE values (73.0 ± 8.3 kg). The same trend was also found in skeletal muscle mass and fat mass. The change in body mass and in skeletal muscle mass correlated negatively with the change in vigorous physical activity ($r = -0.374$, $p = 0.016$, and $r = -0.337$, $p = 0.031$, respectively). Muscular endurance decreased significantly ($p < 0.001$) in sit-ups from the PRE (46 ± 9 reps/min) values compared with MID (40 ± 8 reps/min), POST (42 ± 8 reps/min), and RECO (34 ± 11 reps/min) values. Also in push-ups, the declines in the POST (34 ± 10 reps/min) and RECO (34 ± 13 reps/min) values ($p < 0.001$) from the PRE (40 ± 13 reps/min) and MID (39 ± 12 reps/min) values were observed. There was a significant decrease in a standing long jump in all measurement points MID (220 ± 20 cm), POST (216 ± 20 cm), and RECO (213 ± 20 cm) as compared with the PRE values (229 ± 23 cm, $p < 0.001$). There was no change in 3.2 km loaded march time between the PRE (23:57 ± 4:12 min:s) and POST (23:44 ± 5:02 min:s) measurement time points. In PA, the total number of steps per day was significantly ($p < 0.001$) greater during ST (13,722 ± 2,379 steps) and MFT (13,937 ± 2,276 steps) than during garrison days (9,550 ± 2,569 steps). In POST, there was significantly ($p < 0.001$) more light (1.5–3.0 metabolic equivalent) (2:34:38 ± 0:22:53 h:min:s in ST and 3:03:27 ± 0:23:24 h:min:s in MFT) and moderate (3.0–6.0 metabolic equivalent) (2:12:15 ± 0:23:14 h:min:s in ST and 2:47:59 ± 0:27:23 h:min:s in MFT) PA than in the PRE measurements. Conclusion: This study demonstrated slight decrements in warfighter physical performance during the 21-d MFT. The conscripts were overloaded during MFT, but 4 d of recovery seemed not to be enough to obtain the PRE measurement values in physical performance. This study also showed changes in the muscular endurance levels and PA during the 21-d MFT. It is important for warfighters to have a good physical fitness level PRE training or combat. As the prolonged MFT may have adverse effects in warfighters muscular endurance and PA levels, it is important to have sufficient recovery time after long MFT to regain combat readiness.

INTRODUCTION

It is important that soldiers in the Armed Forces train continuously during peace time to ensure mission readiness. Warfighters deployed in the field are often exposed to different kinds of stressors including physical, psychological, environmental, and nutritional ones. They are required to undergo a combat training in a multistressor environment in order to be ready for similar situations in the case of war. The training can be short or long term, and it can also include courses lasting several weeks.

Military field training (MFT) involves several different kinds of physical activities (e.g., marching long distances with heavy loads; run, jump, and crawl during combat drills; and lift and carry heavy objects), and it also exposes soldiers to multiple other physiological stressors. These stressors include exertional fatigue, sleep deprivation, and energy deficits, which all have been shown to lead to decreased physical performance[1–9] induced by different types of MFT.

In the previous training studies lasted less than 3 wk, MFT has been shown to lead deficits in cardiorespiratory endurance,[10] muscle endurance,[11] ability to produce power of the lower body,[2,6] and decline in body mass (BM), fat mass (FM), and fat-free mass.[1–3,6,10,11] Eight or more weeks of strenuous military training has been shown to cause drastic declines in warfighters' maximal strength and power[5,7,12] and requires an appropriate recovery period from a physiological point of view before deployment. In the past, it has also been demonstrated that the warfighters are often exposed to extended periods of caloric deficit, lack of sleep or disturbed sleep, and high-energy expenditure depending on operational tasks and situation.[3,8]

Previous studies examining responses during MFT have mainly concentrated on hormonal and neuromuscular changes

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while there are limited data available on measured physical activity (PA) during MFT. PA during MFT can be measured by subjective measures such as self-report questionnaires,[13–16] logs, diaries, and by objective measure such as accelerometers[17] and pedometers.

Wyss et al[18] observed during their basic training that PA among Swiss Army training schools varied according to occupational specialties. Simpson et al[19] and Knapik et al[20] measured PA during the US Army Basic Combat Training (BCT) period, but no detailed data on actual MFT have been reported. Aandstad et al[21] found that Norwegian Home Guard soldiers had a higher intensity of PA during civilian life compared with military training, although during military training, the total amount of PA was higher.

Metabolic equivalent (MET) is defined as the ratio of the metabolic rate to the resting metabolic rate. Tudor-Locke et al[22] have classified that over 10,000 steps/d can be classified as a physically active. A MET value is equivalent to 3.5 mL/kg/min, which equals to the oxygen cost of sitting quietly.[23,24] PA can be divided into sedentary (< 1.5 MET), light physical activity (LPA) (1.5–2.99 MET), moderate physical activity (MPA) (3.0–5.99 MET), and vigorous physical activity (VPA) (≥6.0). Vincent et al[25] and Chappel et al[26] have reported PA for firefighters in METs, whereas Redmond et al[27] and Wyss et al[18] have reported MET values for warfighters.

During military training, it is important to mitigate the operational circumstances. MFT typically consists of high psychological and physiological stressors and normally include energy and sleep restriction as well as extreme weather conditions. To study the physiological changes during MFT, examination of the amount of PA is also necessary. Therefore, the purpose of this study was to investigate changes in PA and neuromuscular performance among male Finnish Army conscripts during a 21-d MFT and to evaluate their recovery after MFT. The study also aimed to distinguish whether there were any associations between the above-mentioned variables and to study if 4 d of recovery at the end of the prolonged combat training period was enough to return all of the measured variables to the baseline level.

METHODS

Subjects

Sixty-one ($n = 61$) Finnish Army male conscripts who were doing their compulsory service volunteered as subjects for this study. This study was a part of a larger study and included also physiological measurements that will be reported separately. Twelve individuals dropped out mainly due to discomfort of having to give blood samples and the lack of motivation to participate in the study. Therefore, 49 subjects completed the study. The subjects were 19- to 22-yr-old male conscripts. The mean (± SD) age was 20 ± 1 yr, height of 179 ± 6 cm, BM 73.5 ± 8.7 kg, and body fat 12.6 ± 5.0%.

Before the study, all the subjects were fully informed of the experimental design and the possible risks that could be associated with it. The subjects were informed that they could cancel their participation in this study at any stage if they so wished without any consequences. Every subject signed an informed consent before the study commenced. This study was conducted according to the provisions of the Declaration of Helsinki and was granted ethics approval by the Ethics Committee of the University of Jyväskylä. The study was also approved by the Finnish Defence Forces.

Experimental Design

A week before MFT (PRE), all the subjects were tested for baseline of the study. The same tests were also performed on the 12th day of the MFT, in the end of MFT, and after a recovery period of 4 d. Body composition, muscle endurance tests (sit-ups and push-ups), and standing long jump were measured during the measurement days. PA was monitored PRE, throughout the whole 21-d MFT, and also after the recovery period. Daily diaries were collected to follow the workload and mood states of the conscripts.

The PRE measurement week was a normal training week for the conscripts at the garrison. They had lectures in the classroom, rifle maintenance, and preparation for MFT. The entire 21-d MFT period, which was divided into three phases, was performed in field conditions.

During the first phase (shooting training [ST]), the subjects performed combat drills and shooting exercises with live ammunition. The goal for each conscript was to improve their combat and shooting skills and advance their weapon-handling abilities. In this phase, the objective was not to physically exhaust the conscripts but rather to ensure that each of them maintained a high level of performance by ensuring that they had an appropriate amount of rest and sleep. The normal training day started at 07:00 and ended not later than 19:00 o'clock.

In the second phase (MFT), they practiced moving from their base to their attacking positions for the last phase. The tasks performed included reconnaissance, combat maneuvers, patrolling, and tactical road marches. In the third and last phase (MFT), they executed their combat mission as a part of larger military exercise. The tasks were the same as in the second phase. After the prolonged MFT, the subjects had 4 d of recovery, two at home, and two at the garrison before the final measurements were taken.

Measurements

Body Composition

BM, skeletal muscle mass (SMM), and FM were determined using bioelectrical impedance analysis (InBody 720, Biospace Ltd, Seoul, South Korea). The measurement was taken after an overnight fast, in the morning between 06:00 and 07:00. The subjects were instructed not to eat anything after their evening meal, which was around 19:00. The bioelectrical impedance analysis estimates of body composition have shown to highly correlate with the dual-energy X-ray absorptiometry method (r = 0.82–0.95).[28]

Aerobic Performance

Aerobic performance was measured with a 3.2-km March Test[29,30] before and after MFT. The load during the March Test was 20 kg and it was performed on the same track at both times, and the total time was measured. The conscripts also performed a 12-min running test PRE training.[31] It was performed in a 400-m track at garrisons.

Standing Long Jump and Muscle Endurance Tests

Standard Finnish Army fitness tests (standing long jump and muscle endurance tests, sit-ups, and push-ups) were measured before and after MFT and after 4 d of recovery. In the standing long jump, the conscripts had three attempts, and the best result was selected for further analysis. The jumps were performed in sport clothing in an indoor gym. For muscle endurance tests, the participants were instructed to perform as many repetitions in sit-ups and push-ups, as they were able to do during 60 s. There was a recovery period of at least 5 min between the tests. Before each test, participants were instructed to use correct technique. Only the completed trials with adequate technique were accepted for final results. Standing long jump has been shown to be highly repeatable (CC = 0.95).[32] Similar findings have been shown also for sit-ups (CC = 0.93–0.95) and push-ups (CC = 0.83–0.93).[33]

Physical Activity

PA was monitored using a tri-axial accelerometer (Hookie AM20; Traxmeet Ltd, Espoo, Finland). The device was attached to the waist with an elastic belt. The validity (CC = 0.96) of the device has been reported by Vähä-Ypyä et al.[34] The device measured several different variables including the total number of steps, running steps, and intensity of activity by categorizing it according to METs during each day.[35] The subjects were instructed to keep the accelerometer on them at all times. The acceleration data were collected in raw mode (milligravity, mg). After the measurement period, the stored data were transferred to a hard disk and analyzed in 6-s epochs. We used cut-points, which have been previously determined from adults' raw acceleration data by using mean amplitude deviation, were used to classify the intensity or employees' intensity-specific PA (light, moderate, and vigorous), and to separate SB from PA.[34] PA was analyzed and presented for the following variables: number of steps; running steps; METs; sitting and standing time; time in LPA (1.5–3.0 METs), MPA (3.0–6.0 METs), VPA (>6.0 METs); and with the highest average MET in 1, 3, 10, 20, and 60 min and for the whole day.

Questionnaires

Questionnaires were used to collect information concerning the amount of sleep, stress levels, fatigue, and several other factors. Each morning, the conscripts were given a new diary to fill in, and in the next morning, the previous diary was collected. The subjects were asked to write down how many hours they slept each night to the nearest half an hour (e.g., 7.5 h) and to rate the ratio of perceived exertion (RPE) of the whole previous day. The RPE was measured on a scale of 6–20, 6 means very light and 20 means very heavy physical exertion.[36]

Statistical Analysis

The data for this study was analyzed using SPSS Statistics 22 program. For calculating means, standard deviations, and Pearson's product moment correlation coefficients, conventional statistics were used. The data were analyzed using multivariate analysis of variance with repeated measures. Probability-adjusted t-tests were used for pairwise comparisons when appropriate. A general linear model, with repeated measures analysis of variance was used to analyze the differences between the different measuring points. Bivariate correlation was used for correlation analysis where the changes in the variables between the different time points were tested. Also the simple regression analysis was used. The $p < 0.05$ criterion was used for establishing the statistical significance.

RESULTS

Anthropometry

The declines in BM, SMM, and FM after MFT were all significant, and the values recovered during the 4-d recovery period, except BM and SMM, which did not returned to the PRE values. BM declined from 73.5 ± 8.7 to 71.6 ± 8.2 kg but recovered to 73.0 ± 8.3 kg as seen in Table I. The same trend was found also in SMM and FM. The change in BM and in SMM correlated negatively with the change in VPA ($r = -0.374$; $p = 0.016$ and $r = -0.337$; $p = 0.031$, respectively) as seen in Table IV.

Physical Performance

As Table II demonstrates, sit-ups declined from the PRE (46 ± 9 reps/min) values to both MID (40 ± 8 reps/min) and POST (42 ± 8 reps/min) measurement points (all, $p < 0.001$) and declined even more for RECO (34 ± 11 reps/min) measurement.

TABLE I. Changes in Body Composition

Body Composition	PRE	POST	RECO
BM (kg)	73.5 ± 8.7	71.6 ± 8.2***	73.0 ± 8.3*†††
SMM (kg)	36.4 ± 3.9	35.9 ± 3.8***	36.1 ± 3.9*†††
FM (kg)	9.5 ± 4.6	8.4 ± 4.0***	9.6 ± 4.1†††
Fat %	12.6 ± 5.0	11.6 ± 4.4***	12.9 ± 4.5†††

POST, post training measurements; RECO, recovery measurements.
*$p < 0.05$.
***,†††$p < 0.001$.
*, ***, compared to the PRE values.
††† = Compared to the after 12 d (MID) values.

In push-ups, declines in the POST (34 ± 10 reps/min) and RECO (34 ± 13 reps/min) measurements ($p < 0.001$) from the PRE (40 ± 13 reps/min) and MID (39 ± 12 reps/min) values were observed. Standing long jump declined in all measurement points MID (220 ± 20 cm), POST (216 ± 20 cm), and RECO (213 ± 20 cm) as compared with the PRE (229 ± 23 cm) values ($p < 0.001$). In addition, there was a declining trend from MID to POST ($p < 0.01$) and from POST to RECO ($p < 0.05$). There was no change ($p > 0.05$) in 3.2 km loaded march time between the PRE (23:57 ± 4:12 min:s) and POST (23:44 ± 5:02 min:s) measurement points. No correlations were found with the changes in physical performance and other measured variables.

Physical Activity

As seen in Table III, the total number of steps per day was significantly ($p < 0.001$) greater during ST and MFT than during the garrison days. Running steps seemed to be linked to the daily program and were higher during the PRE measurements because of strenuous physical training. There was significantly ($p < 0.001$) more light (1.5–3.0 MET) and moderate (3.0–6.0 MET) PA during ST and MFT than in the PRE measurements. VPA (>6.0 MET) was significantly lower during MFT than during PRE, ST, and RECO. Also the number of running steps was higher during the ST and PRE measurement compared with MFT and RECO. The highest average MET values were found during ST when looking at 1, 3, 10, 20, or 60-min time period. The highest daily average was found during MFT. There were no correlations in the changes between PA and physical performance.

Questionnaires

The RPE was significantly ($p < 0.001$) higher during MFT, and the conscripts slept more ($p < 0.001$) during MFT than at the other measurement points. The change in PRE compared with the change in the push-up test correlated significantly ($r = -0.408$, $p = 0.007$) as seen in Table IV. There was no significant correlation between RPE and other muscle endurance tests or body composition.

DISCUSSION

This study demonstrated slight decrements in physical performance of warfighters, changes in the muscular endurance levels, PA, and body composition during the 21-d MFT.

The conscripts were overloaded during MFT, but 4 d of recovery seemed not to be enough to obtain the PRE measurement values in physical performance. It is important for warfighters to have a good physical fitness level PRE or combat. As the prolonged MFT may have adverse effects in warfighters' muscular endurance and PA levels, it is important to have

TABLE II. Changes in Physical Performance

Physical Performance	PRE	MID	POST	RECO
Sit-ups (reps/min)	46 ± 9	40 ± 8***	42 ± 8***	34 ± 11***†††‡‡‡
Push-ups (reps/min)	40 ± 13	39 ± 12	34 ± 10***†††	34 ± 13**†
Standing long jump (cm)	229 ± 23	220 ± 20***	216 ± 20***††	213 ± 20***†††‡
3.2 km march (min:s)	23:57 ± 4:12		23:44 ± 5:04	

MID, after 12 d measurements; POST, post training measurements; RECO, recovery measurements; *,†,‡$p < 0.05$; **,††,‡‡$p < 0.01$; ***,†††,‡‡‡$p < 0.001$; *, **, ***, compared with the PRE values; †, ††, ††† = compared with the MID values; ‡, ‡‡, ‡‡‡ = compared with POST values.

TABLE III. Changes in PA, Sleep, and RPE

Activity	PRE	ST	MFT	RECO
Sitting (h:min:s)	7:11:18 ± 1:05:28	8:27:38 ± 1:10:57***	7:56:54 ± 0:50:10**††	5:53:26 ± 1:38:09***†††‡‡‡
Standing (h:min:s)	2:32:49 ± 0:53:06	2:21:19 ± 0:38:37	2:18:00 ± 0:29:26*	1:58:19 ± 0:38:20***†††‡‡
MET 1.5–3.0 (h:min:s)	1:44:49 ± 0:20:03	2:34:38 ± 0:22:53***	3:03:27 ± 0:23:24***†††	1:40:17 ± 0:22:22†††‡‡‡
MET 3.0–6.0 (h:min:s)	1:23:16 ± 0:22:02	2:12:15 ± 0:23:14***	2:47:59 ± 0:27:23***†††	1:08:03 ± 0:14:48***†††‡‡‡
MET > 6 (h:min:s)	0:12:42 ± 0:10:03	0:12:50 ± 0:05:39	0:03:35 ± 0:01:52***†††	0:10:13 ± 0:06:35††‡‡‡
Steps	9,550 ± 2,569	13,722 ± 2,379***	13,937 ± 2,276***	7,974 ± 1,803**†††‡‡‡
Running steps	699 ± 658	1,306 ± 502***	381 ± 205**†††	415 ± 266***†††
MET1min	9.18 ± 2.38	9.95 ± 1.41*	7.59 ± 1.08***†††	8.12 ± 1.88*†††
MET3min	6.58 ± 1.01	7.93 ± 1.14***	5.61 ± 0.61***†††	6.21 ± 1.01†††‡‡‡
MET10min	4.47 ± 0.58	5.82 ± 0.86***	4.21 ± 0.27**†††	4.30 ± 0.48†††
MET20min	3.05 ± 0.52	4.21 ± 0.58***	3.39 ± 0.17***†††	3.01 ± 0.33†††‡‡‡
MET60min	2.54 ± 0.47	3.38 ± 0.42***	2.96 ± 0.14***†††	2.44 ± 0.24†††‡‡‡
METday	1.49 ± 0.02	1.56 ± 0.01***	1.60 ± 0.01***†	1.48 ± 0.12†††‡‡‡
Sleep (h)	5.7 ± 0.6	5.6 ± 0.8	6.1 ± 0.8**†††	5.7 ± 1.2‡
RPE	8.4 ± 1.4	10.2 ± 1.6***	9.4 ± 1.5**††	7.1 ± 1.3***†††‡‡‡

PRE, Pre measurements; RECO, Recovery measurements; *,†,‡ = $p < 0.05$; **,††,‡‡ = $p < 0.01$; ***,†††,‡‡‡ = $p < 0.001$; *, **, ***, compared with the PRE values; †, ††, ††† = compared with the MID values; ‡, ‡‡, ‡‡‡ = compared with POST values.

TABLE IV. Correlation Coefficients Between the Changes in Muscular Endurance, Aerobic Performance and Body Composition Compared with Changes in PA, Sleep, and RPE

	Sit-ups		Push-ups		Standing Long Jump		3.2 km March		BM		SMM		FM	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*	*r*	*p*
LPA	0.004	0.981	−0.097	0.552	0.051	0.750	−0.126	0.458	−0.19	0.417	−0.035	0.826	−0.09	0.574
MPA	0.017	0.918	−0.158	0.329	−0.120	0.455	0.058	0.732	−0.213	0.180	−0.234	0.140	−0.029	0.858
VPA	0.092	0.566	0.109	0.502	−0.117	0.466	0.010	0.952	*−0.374*	*0.016**	*−0.337*	*0.031**	−0.086	0.593
Steps	0.137	0.392	−0.128	0.433	−0.186	0.243	−0.210	0.213	−0.226	0.156	−0.219	0.169	−0.095	0.553
Sleep	0.007	0.965	−0.001	0.996	−0.062	0.686	0.053	0.741	0.073	0.632	0.194	0.203	−0.109	0.477
RPE	0.077	0.626	*−0.408*	*0.007***	0.166	0.287	0.182	0.262	−0.031	0.842	−0.005	0.977	0.001	0.994

*$p < 0.05$; **$p < 0.01$.
Significant changes marked in italic.

sufficient recovery time after long MFT to regain combat readiness.

BM, SMM, and FM declined during the 21-d MFT but seemed to recover after 4 d to the PRE value level. Previous studies[1–3,6] have demonstrated the decline in BM, FM, and fat-free mass after short-term (<14 d) MFT. In addition, more than 8 wk of strenuous military training seems to cause even drastic declines in warfighters body composition.[5,7,12] During long deployments, BM has been reported to both decline[11,14,37] and increase.[38]

Energy deficit has been reported in earlier studies as a main reason for changes in body composition.[1,3] The work of a warfighter during MFT requires more energy than they get from food. Strenuous military training can lead to decreased BM, not only by decreased FM but also with the decrease in fat-free mass. Therefore, it is important from a physiological point of view to have a sufficient recovery period before deployment.

During this study, the soldiers ate regularly three meals during a day. All the meals were made by the maintenance corps in the field near the troops and the quantity of calories was 3,300–3,500 kcal/d. As observed from the data of the activity measurements, the MFT had recovery days and the energy deficit was not so great all the time. It suggests that this was the main reason why the changes in body composition were not as drastic as reported in previous studies.

This study also demonstrated decrements in warfighters' physical performance during the 21-d MFT. Muscle endurance declined both in sit-ups and in push-ups. The decline was found in the MID measurements for sit-ups and in POST measurements for push-ups. In previous studies, Rintamäki et al[11] have reported a decline in muscle endurance after MFT. The difference in sit-ups and push-ups might be due to the tasks the conscripts performed during MFT. They did not have to carry any heavy loads for long distances during the ST phase of the study. Load carriage performance has been linked to improvement in upper body strength.[20] Muscular endurance has declined or stayed the same during previous MFT studies.[5,6] The decline in muscular endurance was probably partly explained by the motivation of the conscripts to perform these tests, but they were verbally encouraged to do their maximum effort in all measurement points. Load carriage, living outdoors, and energy deficit may have influenced their ability to reach the PRE values in sit-ups and push-ups.

There was also the significant decline in lower body explosive strength (standing long jump) in all measurement points. Nindl et al[5] and Chester et al[2] have found that lower body explosive strength measured with vertical jump declined after MFT. It seems that long and high PA will negatively affect neuromuscular performance such as standing long jump. Besides the high volume of walking during MFT, load carriage tasks are a factor related to the decline in neuromuscular function.[39] Load carriage has also been shown to increase ground reaction force[40] and, therefore, during the long MFT, load carriage may cause a decline in neuromuscular function. In special force courses, a decrease in vertical jump has also been observed.[5,12] The possible mechanisms for the decline in neuromuscular function may include neural overtraining, incidence of muscle microtrauma, and/or decreased viscoelastic properties.

No chance occurred in 3.2 km march time. It seems that the conscripts' neuromuscular capacity was overloaded during MFT. Four days of recovery did not seem to be enough to regain the PRE values. The results suggest that it is important to have enough recovery time after long MFT. Previous studies have shown a decline or no change in aerobic performance during MFT. The more the intensive MFT has been, the more decline has been observed in the physical performance variables.

Measured PA was significantly higher during MFT than in the PRE measurement. The amount of light and moderate PA during MFT was two times greater than in the PRE measurements. The conscript took almost 50% more steps in MFT. When comparing the amount of steps taken during MFT, it can be concluded that the average of 13,937 ± 2,276 steps/d during MFT can be defined as highly active when compared with healthy adults.[22,41] Tudor-Locke et al[22] have classified that over 10,000 steps/d can be classified as physically active. Schulze at al[42] have reported in the German Army that only the junior enlisted soldiers reached over 10,000 steps in a day while non-commissioned officers and officers did not reach 10,000 steps/d.

In another study made with German Soldiers at work and during leisure time, it was found that the average step count was 8,500 during a day and only 41 soldiers out of 169 reached the recommend step count of 10,000 steps/d.[43] Rintamäki et al[11] reported on average 5,797 steps taken during a 12 -h working time in peacekeeping operation in Chad. Aanstadt et al[21] have found in their study in Norwegian Home Guard – troops that the average step count did not increase during military training when compared with civilian life (average 10,500). The average VPA during military training was significantly lower than during civilian life, but there was more MPA during military training compared with civilian life.

Knapik et al[20] have studied PA during the entire US Army BCT with electronic pedometers. The study showed that trainees performed an average of 16,311 ± 5,826 steps/d and the highest daily average was found during the field training exercise in which the trainees took an average of 22,372 ± 12,517 steps/d. During this study, the highest daily average was 19,724 ± 4,169 steps/d (Fig. 1) and the whole MFT averaged to be 13,937 ± 2,276 steps/d (Table III). Thus, it was lower when compared with Knapik's[20] results, but higher than in the studies of Schultze[42] and Aanstadt.[21] The average daily step count with physically healthy, free-living adults using electronic pedometers were about 7,000–8,000 steps/d.[20] In the studies done by pedometers, it is impossible to distinguish between steps taken during walking and running. The accelerometer and algorithms used in our study made it possible to measure the running steps taken and also the level of activity in MET.

When we look at activity as a level of MET, Vincent et al[25] have found that firefighters had average of 7:33:00 h of light activity, 2:36:00 h of moderate activity, and 0:01:00 h of vigorous activity. Chappel et al[26] had similar findings also with firefighters 7:10:00 h of LPA, 2:32:00 h of MPA, and 0:00:02 h of VPA. Simpson et al[19] have showed that when measured with accelerometer during US Army BCT, the recruits had on average 7:25:30 h of sedentary activity, 2:20:30 h of light activity (>3.0 MET), 1:32:00 h of moderate activity (3.0–6.0 MET), and 0:38:00 h of vigorous activity (>6.0 MET) during a training day. Wyss et al[18] have studied Swiss conscripts and found that they had LPA 7:33:00–8:40:00, MPA 3:45:00–5:46:00, and VPA 0:05:00–0:16:00 h:min:s per training day. In the same study, they found that the distance covered per day was greater than in a study made by Knapik et al[20] (15.6 km/d vs. 11.7 km/d).

In this study, we found that the average MPA during ST was 2:12:00 h and during MFT 2:48:00 h. That was close to firefighters' MPA during their regular shift[25,26] and more than the recruits during US Army BCT,[19] but less than the Swiss conscripts[18] during their training. All these studies showed that there was only a couple of minutes VPA during the measured days, thus almost all the activity was either light or moderate.

As observed in Table IV, no significant correlations were found between physical performance and activity. The change in BM and SMM correlated negatively with the change in VPA ($r = -0.374$; $p = 0.016$ and $r = -0.337$; $p = 0.031$). Also PRE and the change in push-ups correlated negatively ($r = -0.408$; $p = 0.007$).

One limitation to this study was that we did not objectively measure the amount of sleep the conscript have per night. Also there was variation on the tasks the conscripts did. Few of them were drivers, so they did not have to walk as much as the others. But the variation of activity was not drastic. In the POST measurements, one could see that the motivation of the conscripts was not as good as it could have been. This might have influenced the muscular endurance and 3.2 km march time.

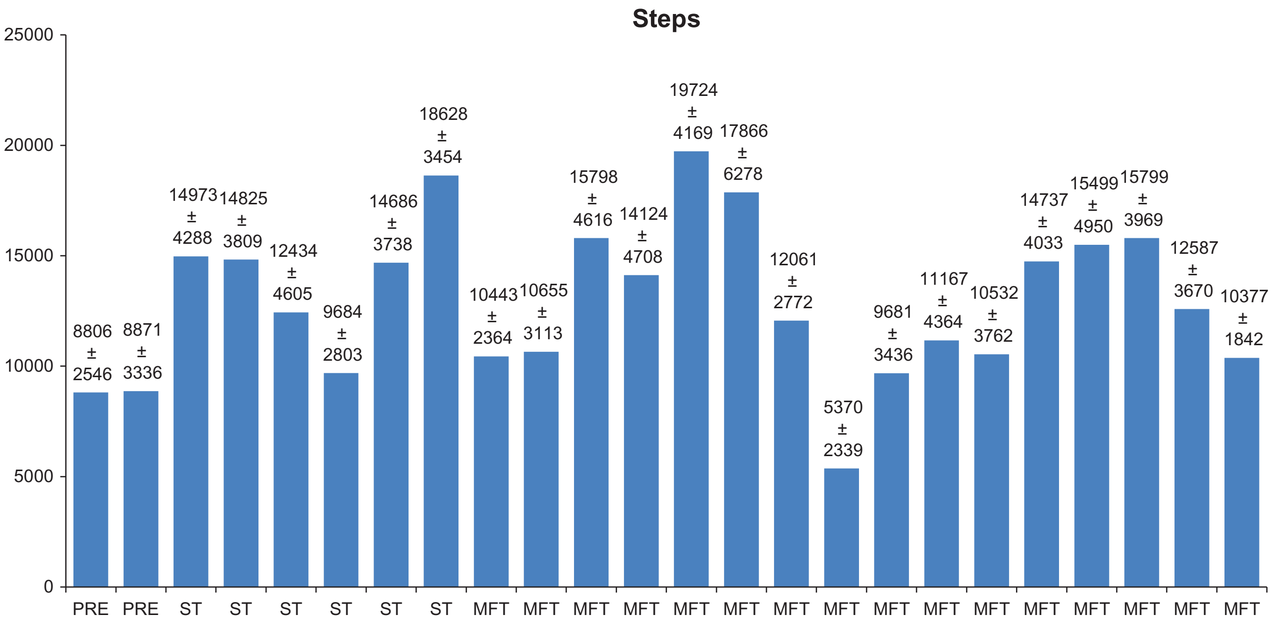

FIGURE 1. Daily mean and standard deviation of steps of all the participants during the study days.

It can be concluded that during MFT, there was significantly more PA than during an usual garrison training week. ST seems to have more intensive PA, but not a higher total amount of steps. ST had more anaerobic type of activity and more rest time during the nights. MFT was more aerobic type, and the PA was divided into longer time frame during a day. Due to the higher PA, prolonged MFT seems to lead to energy deficit and to decreases in BM, SMM, and FM. Body composition seems to recover during a short-term recovery time. Regarding physical performance, muscle endurance seems to decrease after MFT. This was also observed in lower body muscle power. There was no change in 3.2 km march time including that aerobic performance stayed almost the same. This study shows that the recovery from prolonged MFT seems to take more time than 4 d when looked at the muscular endurance and lower body muscle power. It might be advisable to have a low-intensity week after the prolonged MFT to ensure the recovery of a warfighter.

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II

EFFECT OF PROLONGED MILITARY FIELD TRAINING ON NEUROMUSCULAR AND HORMONAL RESPONSES AND SHOOTING PERFORMANCE IN WARFIGHTERS

by

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Effect of Prolonged Military Field Training on Neuromuscular and Hormonal Responses and Shooting Performance in Warfighters

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ABSTRACT Introduction: Previous studies have shown that military field training (MFT) has effects on warfighters' hormonal responses, neuromuscular performance, and shooting accuracy. The aim of the present study was to investigate the changes in body composition, upper and lower body strength, serum hormone concentrations of testosterone (TES) and cortisol (COR), insulin-like growth factor-1 (IGF-1), and sex hormone binding globulin (SHBG) and shooting accuracy during prolonged MFT. Methods: Serum hormone concentrations, isometric strength of the upper and lower extremities, and shooting performance were measured four times during the study: before MFT (PRE), after 12 d (MID), at the end of MFT (POST) and after 4 d recovery (RECO). The study was approved by the Finnish Defence Forces and was granted ethical approval by the Ethical Committee of the University of Jyväskylä. Results: There was no change in prone shooting score between the measuring points. In the standing position, however, there was a significant ($p \leq 0.001$) decrease from PRE 58.2 ± 12.3 points to MID 45.2 ± 10.4 points. Also POST 61.4 ± 10.8 points and RECO 56.8 ± 13.6 points were significantly ($p \leq 0.001$) higher than MID 45.2 ± 10.4 points. Serum hormone concentrations of TES and IGF-1 decreased significantly during MFT. In COR and SHBG concentrations, significant increases were observed during MFT. Individual changes in lower body strength and changes in shooting standing score between the measurement points (PRE–MID/POST/RECO) correlated significantly ($r = 0.332$, $p = 0.031$; $r = 0.335$, $p = 0.025$; $r = 0.489$, $p = 0.001$, respectively). The similar finding was observed with changes in upper body strength and changes in standing shooting between the PRE and RECO measurement points (0.339, $p = 0.010$). The changes in COR and the changes in prone shooting showed a positive correlation in all measurement points ($r = 0.531$, $p \leq 0.001$; $r = 0.337$, $p = 0.024$; $r = 0.572$, $p \leq 0.001$). The changes in IGF-1 correlated negatively ($r = -0.325$, $p = 0.038$) with shooting prone between the PRE and MID measurement points. The changes in shooting standing and the changes in TES between PRE and POST correlated negatively ($r = -0.378$, $p = 0.010$). Conclusion: In this study, we observed a decrease in leg strength from the PRE to MID measurements. When the physical load requirements during the MFT decreased after the MID measurements, leg strength increased. In addition, the shooting score from the standing position decreased from the PRE to MID measurements and improved significantly from the MID to POST measurements. The prone shooting score did not show any significant changes during the study period. Significant positive correlations were found between the changes in standing shooting score and the changes in strength for the legs and upper body. There was a positive correlation between the changes in serum COR concentrations and changes in standing shooting score. Altogether, the present study showed that the prolonged MFT has adverse effect on the strength levels and the shooting ability in warfighters. This shows that ensuring warfighters get an appropriate amount of rest while performing their duties is important. Shooting from a prone position was not affected by the changing workloads and this result indicated that soldiers should shoot from a prone position, whenever possible, especially when fatigued.

INTRODUCTION

Warfighters are exposed to physical, environmental, and mental stressors when training for military operations. These stressors include factors such as physical and cognitive fatigue caused as a consequence of prolonged physical exertion and/or sleep deprivation and insufficient energy and fluid intake. During military field training (MFT), these factors have shown to cause disruptions in hormonal balance,[1–4] leading to reduced physical and cognitive performance,[5–9] extended recovery times,[10] and increased susceptibility to infections.[11] How this kind of environment effects on warfighters' hormonal responses, neuromuscular performance, and shooting accuracy and the consequences of these stressors and their influence on health, physical performance level and work capacity of a warfighter are of vital importance to commanders.

Previous studies have examined various biomarkers in warfighters in relation to nutrition status, fluid intake, body composition,[5,12] prolonged physical exertion, neuromuscular performance,[6,13] and sleep deprivation.[14,15] Decrements in lower and upper body strength have been demonstrated after a prolonged MFT. The type of loading is a key determinant to which part of the body becomes fatigued.[2,6,7,13] In order to carry out daily duties, warfighters must have good muscle strength capability.[16] Even in the face of technological developments in the military field, the modern warfighter tasks are, however, physically very demanding. Both lower and upper body strength must be considered: marching long

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distances require a warfighter to have a strong lower body, while for lifting and carrying heavy equipment, a warfighter must have good upper body strength.[7,17] The modern warfighter needs power and strength as well as aerobic capacity and muscular endurance. The optimal level of either one is dependent on occupational tasks of a warfighter.[18] Multiple studies have also demonstrated that strength training and higher strength levels coincide with lower injury levels, particularly in the lower extremities.[19,20]

The impact of MFT on hormonal changes is well demonstrated. Cortisol (COR) and sex hormone binding globulin (SHBG) concentrations have been shown to increase during prolonged MFT,[1,3,7,21–23] whereas testosterone (TES) and insulin-like growth factor-1 (IGF-1) concentrations have been shown to decrease[1,6,21,24–28] Friedl et al found that during US Army Ranger training a warfighter lost 15% in body mass, 7% in fat free mass, and 65% of their fat mass. Nindl et al studied the effects of short term MFT on hormonal responses. The study showed that there was a 3% loss in body mass and 24 to 30% loss in free TES levels. Kyröläinen et al found that during the first couple of days of strenuous MFT there was a significant increase in COR levels (32%) and a decrease in TES levels (27%). Also, SHBG levels have been found to increase during basic military training[23] and during heavy and strenuous MFT.[26]

Shooting is one of the most important occupational skills for a warfighter. There is limited information regarding shooting performance and how it is affected by prolonged MFT. It has been shown that shooting performance differs as a result of different loading intensities.[29–33] Warfighters are required to move on the battlefield, and maximizing shot accuracy in a state of increased heart rate and fatigue.[31] Several factors affect the accuracy of shooting in warfighters. Anxiety has been shown to decrease the accuracy of shooting as well as a negatively impact on decision making.[34] Fatigue is also a significant factor affecting marksmanship, especially after anaerobic physical strain.[30–32] In addition to anxiety and fatigue, sleep deprivation has shown a detrimental effect on the shooting accuracy. Research on how prolonged MFT in a multistressor environment affects the warfighters shooting performance is lacking.[33]

The aim of the present study was to investigate the changes in body composition, upper and lower body strength, serum hormone (TES, COR, SHBG, IGF-1) concentrations, and shooting accuracy during a prolonged MFT. We hypothesized that we would observe declines in all measured variables and the study would provide better understanding of the associations between warfighters physical performance and shooting capability during MFT.

METHODS

Subjects

Sixty-one ($n = 61$) male subjects volunteered for the present study. Each subject (conscript) was a Finnish Army member conducting infantry training, performed during their 6-mo mandatory service in the Finnish Defence Forces. Based on exit interviews, 12 individuals dropped out due to discomfort of having to give blood samples and unsustained motivation to participate in the study. Forty-nine subjects between 19 and 22 yr of age completed the study. The mean (±standard deviation) age was 20 ± 1 yr, height of 179 ± 6 cm, body mass 73.5 ± 8.7 kg and body fat 12.6 ± 5.0 %.

All subjects were fully informed of the experimental design and possible risks, and every subject signed an informed consent before the study commenced. The subjects were informed that they could cancel their participation in the present study at any stage if they so wished without any consequences. This study was conducted according to the provisions of the Declaration of Helsinki and was granted ethical approval by the Ethical Committee of the University of Jyväskylä. The study was also approved by the Finnish Defence Forces.

Experimental Design

A week before MFT, all the subjects were tested for their baseline values. The same tests were also performed on the day 12 of MFT, at the end of MFT and after a recovery period of 4 d. Blood samples, isometric strength of the upper and lower extremities, and shooting performance were recorded during the measurement days.

The PRE measurement week was a normal training week for the study participants. Duties included lectures in the classroom, rifle maintenance, and preparation for MFT. The entire 21-day MFT period, which was divided into three phases, was performed in field conditions. During the first phase (ST), the subjects performed combat drills and live-fire shooting exercises. The goal for each conscript was to improve their combat and shooting skills and advance their weapon handling abilities. In this phase, the aim was not to physically exhaust the conscripts but rather to ensure that each of them maintained a high level of performance by ensuring that they had an appropriate amount of rest and sleep. The normal training day started at 07:00 h and ended not later than 19:00 h.

In the second phase (MFT), they practiced moving from their base to their attacking positions. The tasks performed included reconnaissance, combat maneuvers, patrolling, and tactical road marches. In the last phase (MFT), they executed combat mission as a part of larger military exercise. The tasks were the same as in the second phase. After the prolonged MFT, the subjects had 4 d of recovery, 2 at home and 2 at the garrison before the final study measurements were taken.

Measurements

Neuromuscular Performance

Maximal isometric strength of the upper and lower extremities was measured with dynamometers. The measurements were conducted using a leg and bench press dynamometer manufactured by the University of Jyväskylä, Department of Biology of Physical Activity, Finland. The knee angle was set to 107 degrees.[35] During the maximal strength test for upper extremities, the equipment was adjusted for each subject so that when in sitting position with their feet flat on the floor their arms were parallel to the floor and the elbow angle was 90 degrees. The test was performed by pushing the bar horizontally. The subjects were given one trial attempt before the two actual test trials were conducted on both leg extension and bench press. The subjects were instructed to produce maximal force as fast as possible in both leg extension and bench press. On all trials, the testing personnel encouraged them vocally during the maximal effort. The best performance was selected for analysis.

Serum Hormone Concentrations

Venous blood samples were drawn four times from the antecubital vein after an overnight fast between 0630 and 0730 to analyze TES, COR, SHBG, and IGF-1 (Siemens Immulite 2000 XPI, Siemens Healthcare, USA). Interassay coefficients of variance were 9.4% for TES, 7,6% for COR, 5.6% for SHBG, and 6.7% for IGF-1. The samples were centrifuged (Megafire 1.0 R Heraeus, DJB Lab Care, Germany) at 3,500 rpm for 10 min and frozen and transported to the laboratory for later analysis.

Shooting

The shooting test was performed from both prone and standing positions. First, the conscripts fired 10 shots at the target from a prone position and then 10 shots from a standing position. The best possible score was 100 points, and the result for each person was given at an accuracy of 0.1 points. The shooting test was performed indoors and the target was ten meters away in both prone and standing positions. The weapon system used (Eko-Aims Oy, Ylämylly, Finland) was similar to the Army assault rifle (RK95, Finland) which the conscripts handled daily. Because the tests were performed indoors the conditions were the same in all measurement periods. The sum of 10 shots from both positions was recorded for analysis.

Statistical Analysis

The data were analyzed using IBM SPSS Statistics 22.0 (IBM Corporation, Armonk, NY, USA). Statistical analysis included descriptive statistics, Pearson correlation, and multivariate analysis of variance with repeated measures. Probability adjusted *t*-tests were used for pairwise comparisons. A general linear model, with repeated measures ANOVA was used to analyze the differences between the different measuring points. Bivariate correlation was used for correlation analysis where the changes in the variables between the different time points were tested. The $p < 0.05$ criterion was used for establishing the statistical significance.

RESULTS

Neuromuscular Performance

There was a significant increase ($p \leq 0.05$) in isometric leg press force from MID of 3,406 ± 923 N to POST 3,532 ± 1011 N measurement. No other significant changes were found in leg press. Force of upper body isometric bench press increased significantly ($p \leq 0.001$) from PRE of 890 ± 181 N to MID 929 ± 179 N. There was a decline in POST of 900 ± 179 N ($p \leq 0.05$) and RECO 873 ± 178 N ($p \leq 0.001$) measurements when compared with MID 929 ± 179 N. RECO 873 ± 178 N ($p \leq 0.001$) was also significantly lower than POST of 900 ± 179 N measurement (Table I).

Shooting

There was no change in prone shooting score between the measuring points. In the standing position, however, there was significant ($p \leq 0.001$) decrease from PRE 58.2 ± 12.3 points to MID 45.2 ± 10.4 points. Also POST of 61.4 ± 10.8 points and RECO of 56.8 ± 13.6 points were significantly ($p \leq 0.001$) higher than MID of 45.2 ± 10.4 points (Table I).

Serum Hormone Concentrations

Testosterone

Serum TES concentrations decreased significantly ($p \leq 0.001$) from PRE 18.5 ± 4.5 nmol/L to MID 13.8 ± 4.9 nmol/L (−25.0%) and POST 16.0 ± 4.2 nmol/L (−13.0%). The POST value was also significantly ($p \leq 0.01$) higher (15.9%) than the MID. RECO 19.9 ± 3.7 nmol/L was significantly ($p \leq 0.001$) higher (44.2 %) than MID and POST (24.4 %) and also higher than PRE ($p \leq 0.05$) (8.2 %) (Table II).

Cortisol

There was a significant increase in serum COR concentrations between PRE 301 ± 86 nmol/L and MID 355 ± 76 nmol/L ($p \leq 0.05$) (17.8 %), POST 396 ± 69 nmol/L ($p \leq 0.001$) (31.3 %) and RECO 385 ± 85 nmol/L ($p \leq 0.001$) (27.8 %). Also POST cortisol was significantly ($p \leq 0.001$) higher that of MID (15.9%) (Table II).

Insulin-Like Growth Factor-1

IGF-1 showed a significant ($p \leq 0.001$) reduction from PRE of 40.6 ± 7.7 nmol/L to MID 32.5 ± 8.9 nmol/L (−20.0 %) and POST 32.5 ± 7.7 nmol/L (−20.0 %) Also a significant increase of the same magnitude ($p \leq 0.001$) was observed between RECO of 39.4 ± 7.8 nmol/L and MID (21.2 %) and POST (21.2 %) (Table II).

Sex Hormone Binding Globulin

There was a significant increase in SHBG from PRE of 30.1 ± 7.6 nmol/L to MID 32.8 ± 7.9 nmol/L ($p \leq 0.01$) (9.0 %) and POST of 34.3 ± 9.1 nmol/L ($p \leq 0.001$) (14.0 %). A significant ($p \leq 0.001$) decline was observed between POST and RECO 31.5 ± 8.1 nmol/L (−8.2 %) (Table II).

Associations Between Strength, Shooting, and Serum Hormone Concentrations

In the present study, individual changes in lower body strength and changes in shooting standing score between the measurement points (PRE–MID/POST/RECO) correlated significantly ($r = 0.332$, $p = 0.031$; $r = 0.335$, $p = 0.025$; $r = 0.489$, $p = 0.001$). The same effect was found with changes in upper body strength and changes in shooting standing between PRE and RECO measurement points (0.339, $p = 0.010$). With regard to serum concentrations, a negative correlation was observed between the changes in SHBG and changes in IGF-1 in all measurement points ($r = -0.310$, $p = 0.043$; $r = -0.482$, $p = 0.001$; $r = -0.382$, $p = 0.010$) (Fig. 1). There was also a positive correlation between the changes in SHBG and the change in TES ($r = -0.330$, $p = 0.027$) when comparing the PRE and RECO measurement points. The changes in COR correlated negatively with the changes in TES ($r = -0.341$, $p = 0.025$) and the changes in IGF-1 ($r = -0.346$, $p = 0.023$) between the PRE and MID measurement points. The changes in COR and the changes in shooting prone showed a positive correlation in all measurement points ($r = 0.531$, $p \leq 0.001$; $r = 0.337$, $p = 0.024$; $r = 0.572$, $p \leq 0.001$). The changes in IGF-1 correlated negatively ($r = -0.325$, $p = 0.038$) with shooting prone between the PRE and MID measurement points. The changes in shooting standing and the changes in TES between PRE and POST correlated negatively ($r = -0.378$, $p = 0.010$).

DISCUSSION

Our study supports previous investigations and adds to the existing literature on stressors and key military performance measures. The present study showed the decrease in leg strength from the PRE to MID measurements. When the physical load decreased after the MID measurements, the leg strength increased. In addition, the shooting score from the standing position decreased from the PRE to MID measurements and improved significantly from the MID to POST measurements. The shooting prone score did not show any significant changes during the study period. Serum COR and SHBG concentrations increased from PRE to MID and POST. SHBG increased in RECO measurements, but COR did not change. Serum TES and IGF-1 concentrations decreased during MFT and increased in RECO measurements. Significant positive correlations were found between the changes in standing shooting score and the changes in strength for the legs and upper body. There was a positive correlation between the changes in serum cortisol concentrations and changes in standing shooting score. All the measured variables except cortisol returned close to the baseline level after the recovery period.

Previous military field exercise studies[2,6,7,13] have shown that prolonged physical activity and negative energy balance combined with sleep deprivation have negative impact on neuromuscular performance and hormonal balance of a warfighter. In the present study, maximal upper body strength increased significantly from the PRE to MID measurements,

TABLE I. Mean (±SD) Values of Isometric Strength and Shooting Tests During MFT

Isometric Strength	PRE	MID		POST		RECO	
Bench press (N)	890 ± 181	929 ± 179	***	900 ± 179	†	873 ± 178	*†††‡‡‡
Leg press (N)	3495 ± 931	3406 ± 923	—	3532 ± 1011	†	3424 ± 913	—
Shooting	**PRE**	**MID**		**POST**		**RECO**	
Prone (points)	84.3 ± 11.7	85.5 ± 9.1	—	84.8 ± 11.5	—	87.2 ± 11.0	—
Standing (points)	58.2 ± 12.3	45.2 ± 10.4	***	61.4 ± 10.8	†††	56.8 ± 13.6	†††‡

*, †, ‡ = $p < 0.05$; ***, †††, ‡‡‡ = $p < 0.001$; *, *** = compared with PRE values, ††† = compared with MID values, ‡, ‡‡‡ = compared with POST values.

TABLE II. Mean (±SD) Serum Hormone Concentrations and SHBG Concentrations During MFT

Hormones	PRE	MID		POST		RECO	
TES (nmol/L)	18.4 ± 4.5	13.8 ± 4.9	***	16.0 ± 4.2	***††	19.9 ± 3.7	*†††‡‡‡
COR (nmol/L)	301 ± 86	355 ± 76	*	396 ± 69	***††	385 ± 85	***
IGF-1 (nmol/L)	40.6 ± 7.7	32.5 ± 8.9	***	32.5 ± 7.7	***	39.4 ± 7.8	†††‡‡‡
SHBG (pmol/L)	30.1 ± 7.6	32.8 ± 7.9	**	34.3 ± 9.1	***	31.5 ± 8.1	‡‡‡

* = $p < 0.05$; **, †† = $p < 0.01$; ***, †††, ‡‡‡ = $p < 0.01$; *, **, *** = compared with PRE values, †, ††, ††† = compared with MID values, ‡, ‡‡, ‡‡‡ = compared with POST values.

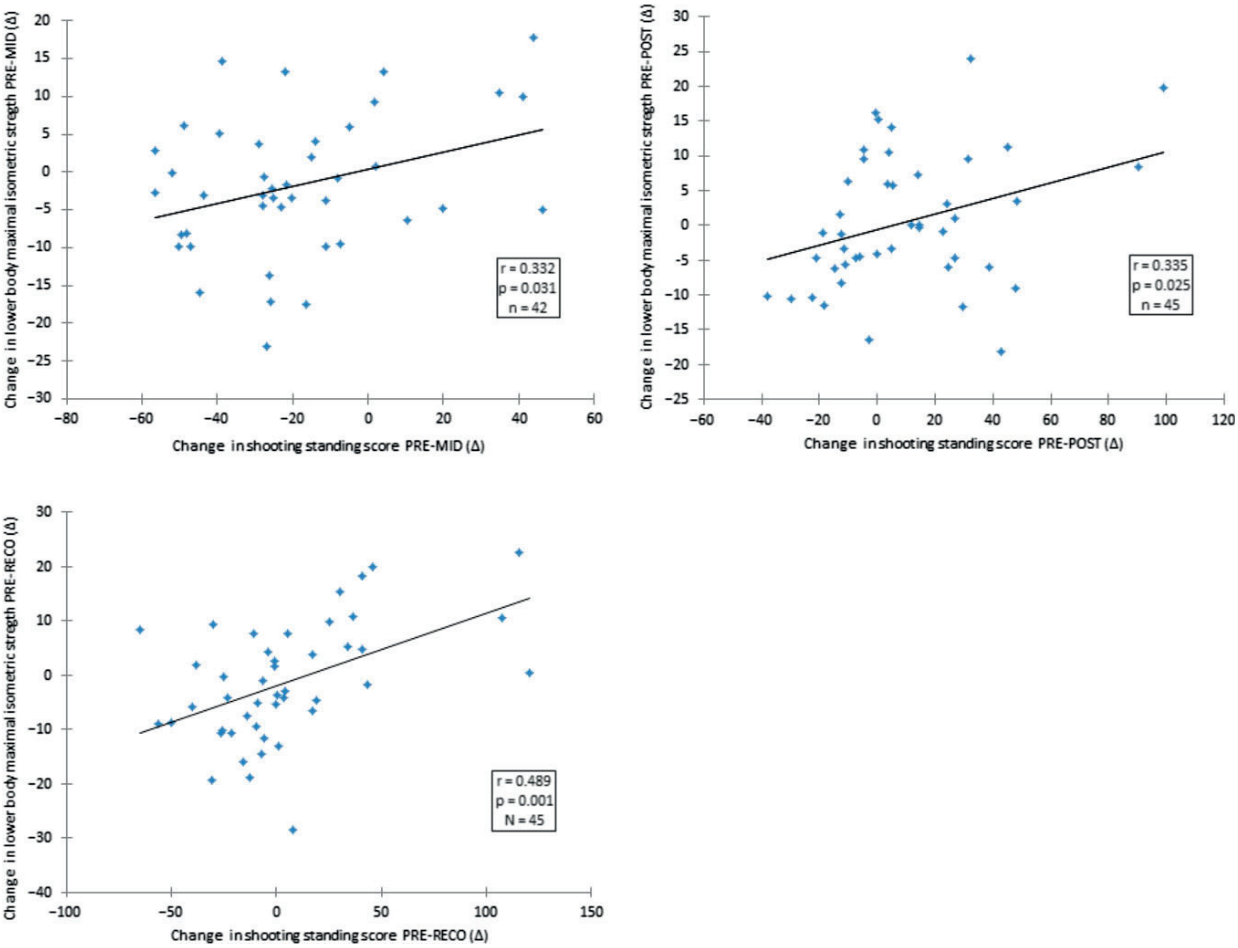

FIGURE 1. Correlations between the lower body maximal isometric strength and shooting standing score between the PRE-MED, PRE-POST and PRE-RECO measurement points.

but decreased back to PRE levels in the POST and RECO measurements. This was probably partly due to learning, but indicated that upper body strength was not affected by prolonged MFT.

It has been shown that lower body strength is an important factor for warfighters to be successful in their duties.[16,17] In the previous studies, the lower body power has been reported both to either decrease or increase[2] after MFT. In the present study, a slight, but not significant, decrease in leg extension values in the MID measurements. This was probably due to the higher loading of the first part of MFT as the 4 d before the MID measurements were physically the most demanding part of MFT. These findings suggest that lower body strength levels are related to the loads of MFT. There were no further declines after the loading was reduced. This indicates that it is possible to recover physically during the present type of MFT. Kyröläinen et al had similar findings with reduced load during prolonged MFT. They showed that a lighter period between two intensive MFT parts can allow strength and hormone levels to recover before the commencing of the second intensive training period.

Serum TES concentration decreased significantly from the PRE to MID (−25.0%) and PRE to POST (−13.0%) measurement. Similar findings have been reported earlier.[1,3,21] A significant increase was observed between MID to POST (15.9%) and POST to RECO (24.4%) measurements. This was probably due to the amount of physical load during MFT, as it was physically harder in the beginning of MFT.

Serum COR concentration on the other hand, increased during MFT (31.3%) and did not return back to resting levels during the recovery period (27.8%). Friedl et al and Nindl et al found similar effect with U.S. Army Rangers. Cortisol concentration increased significantly during the study period, but no recovery period was included. Kyröläinen et al found that during a 20-d MFT cortisol levels increased by 32%. COR, unlike TES and strength values did not begin to increase after the MID measurements. The present results showed that despite the loading was reduced in the latter part of MFT, the stress levels were at highest at the end of MFT, when the warfighters' training reached its capstone exercise.

Previous studies have shown that SHBG concentration has increased during strenuous physical training.[22] In a study with Finnish conscripts, Tanskanen et al showed that SHBG values were elevated during 8 wk of military training. Accordingly, Alemany et al have shown an increase in SHBG during MFT. In the present study, SHBG concentrations increased significantly from the PRE values in the MID (9.0%) and POST (14.0%) measurement points, but returned back to the PRE values in the RECO measurements.

IGF-I is one particular biomarker that has demonstrated a positive relationship between circulating levels and aerobic fitness.[36] Additional biomarkers (e.g., COR, TES, SHBG) have also shown to predict excessive rates of physical performance change. In addition to the ability of biomarkers to predict fitness measures, certain biomarkers that are sensitive to changes in homeostasis may serve as early indicators of stress or overreaching.[3,23,26] Rosendahl et al reported a significant decline in total IGF-1 values after 11 wk of garrison training. There have also been decreases in IGF-1 values after MFT[37] and longer special force training.[6]

In the present study, IGF-1 concentration decreased from the PRE to MID measurements by 20.0%. The values stayed the same from MID to POST and returned back to resting levels in the RECO measurements. Similar findings have been reported in earlier studies.[7,28,38] Even more drastic changes (−62.0%) have been found during special force training.[6] The decrease in IGF-1 concentration is mainly due to physical strain and energy deficit, which has been shown to decrease IGF-1 concentration.[21] This decrease in IGF-1 concentration indicates that warfighters' ability to recovery from physical strain and to repair muscle damage is weakened and can lead to decrease in physical performance. IGF-1 concentration seems to be a good marker to evaluate warfighters' recovery and physical performance.

In previous studies, soldiers' shooting performance has mainly been measured after different simulations of military work. These studies have shown that drastic anaerobic work periods can decrease shooting accuracy, but it has been shown to recover quickly.[33] Evans et al[39] observed the fatiguing upper body obstacle course decreased shooting accuracy significantly, but it recovered quickly. Load carriage has also been shown to decrease shooting accuracy,[40] although it seems that there is no change before the carried loads of 45% of body weight.[34] In a study of Tenan et al, shooting performance was studied during a loaded march with live-fire shooting in the field. They found that load carriage and marching did not affect shooting accuracy, actually the shooting improved with lighter load. In the present study, we found that shooting from the prone position did not alter during MFT. Standing shooting was more sensitive to fatigue, but it seemed to decrease only after the first and most physically demanding part of MFT. Declines in lower body strength and hormonal concentrations have been shown to occur during MFT.[6,7] This might explain the decline in standing shooting score as physical exhaustion causes the heart rate to elevate and influence the shooting mechanisms.[33] More research should be done in the future to investigate the interaction between mechanical and physiological effects and differences in the standing and prone shooting positions in soldiers.

The change in standing shooting score correlated positively with the change in lower body strength. The similar correlation was observed between the change in upper body strength and the change in standing shooting only between the PRE and RECO measurements. It seems that muscular strength, especially in the lower body seems to be important for the standing shooting accuracy of a warfighter during MFT. Both lower and upper body strength seems to be important for enhancing the recovery process and thus the standing shooting accuracy in the recovery phase.

In the RECO measurements almost all the measured values were recovered to the PRE measurement values. Serum COR concentration was significantly higher than in the PRE measurements. Also, body weight (BW) and skeletal muscle mass (SMM) were significantly lower than in the PRE measurements, but had almost recovered to the PRE values. It seems like four days is adequate for the warfighter to recover from the physical strain of the present prolonged MFT in all measured variables except for COR concentration.

The present study had some limitations. Participants were representatives of the larger population doing their military service. A number of the subjects in the study represent only a small fraction of the total number of service members. Thus, some caution should be used when extrapolating the physiological data to the general population. Also, the number of dropped subjects in the study might have had an influence on the results, because most of the dropped subjects were among the poorest half with regard to physical fitness. On the other hand, this might also decrease the motivational effect of the results, when the least motivated subjects were dropped out of the study. The present subjects were familiarized with most of the physical tests, but some new tests were implemented (maximal isometric tests), which could have had some influence in the results due to learning effect. Nevertheless, all the measurements were carefully controlled by the trained researchers, and the tests were completed in the same order and same time of day in all the measurement points.

The strength of the present study was that the conscripts performed similar duties during the study period. In addition, there was a daily control of the subjects and the researchers were able to monitor the loading during the whole study period. The MFT lasted for 21 d, which made it more realistic when compared with short (three to five days) MFTs. The physical loading in the latter part of MFT was lower than expected. This may have influenced the observed measures as they (shooting and isometric maximal strength) did not decline after the MID measurements as expected based on prior studies.

The present study showed that the prolonged MFT has adverse effect on the strength levels and the shooting ability in warfighters. Therefore, to ensure that warfighters get an appropriate amount of rest, while performing their duties is important. Shooting from a prone position was not affected by the changing loads and this result indicated that soldiers should shoot from a prone position, whenever possible, especially when fatigued.

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III

CHANGES IN STRENGTH AND POWER PERFORMANCE AND SERUM HORMONE CONCENTRATIONS DURING 12 WEEKS OF TASK-SPECIFIC OR STRENGTH TRAINING IN CONSCRIPTS

by

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Changes in strength and power performance and serum hormone concentrations during 12 weeks of task-specific or strength training in conscripts

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Abstract

The purpose of this study was to investigate the effects of two different training programs on strength and power performance and serum hormone concentrations. A total of 104 male soldiers volunteered and took part in the 12-week training period with baseline, mid-, and post-measurements of body composition, muscle strength, lower and upper body power, and blood samples to determine serum hormone concentrations. The mean (±*SD*) age of subjects was 20 ± 1 years, height 180 ± 6 cm and body mass 72.4 ± 8.8 kg. The subjects were divided into three different training groups: soldier task-specific training (TS), strength training (ST), and control (CON). Each group had a total of 18 training sessions during the 12-week study. In the muscle strength tests, most improvements could be observed in the TS and ST groups, especially, during the first weeks of the training period. Maximal isometric leg extension force increased significantly by 7.9 ± 12.2% ($p < .05$) in the TS and 7.1 ± 12.6% ($p < .05$) in the ST groups between the PRE and MID, as well as between the PRE and POST measurements by 8.1 ± 12.4% ($p < .05$) in TS and 12.3 ± 15.3% ($p < .01$) in ST. Serum TES concentration increased significantly in TS between the PRE and MID (16.8 ± 33.9%) and PRE and POST (11.2 ± 16.7%) measurements. Serum COR concentrations decreased in TS between the MID and POST (−7.8 ± 10.9%) and PRE and POST (−11.0 ± 14.3%) measurements. Although the differences observed were rather minor in magnitude, training in the TS and ST groups led to greater improvements in muscle strength and power performance compared to the training in the CON group. The development of strength and/or power of the lower and upper body was greater in the TS and ST groups, which is crucial for warfighter's performance. Therefore, it is important to have a structured resistance-training program during military training to optimize the strength, power, and military-specific performance.

KEYWORDS

hormonal, Physical training, power, soldiers, strength

1 | INTRODUCTION

Modern warfighting requires a high level of physical performance so that soldiers would be capable to successfully fulfill missions in the field (Nindl et al., 2013). It is important to have appropriate strength, endurance, and other physical capabilities to perform different military tasks, such as sprinting, lifting, and carrying load over obstacles and in various terrains (Kraemer & Szivak, 2012; Kyröläinen, Pihlainen, Vaara, Ojanen, & Santtila, 2018; Nindl et al., 2017). However, military training in the field consists mainly of prolonged aerobic physical activity with low training intensities. This kind of daily activity could potentially interfere with both optimal muscle strength and maximal aerobic capacity development (Friedl et al., 2015). Despite this, it is still quite uncommon to have structured and periodized training programs for optimal muscular strength and endurance development during military training (Szivak & Kraemer, 2015).

Physical training and consequent adaptations are influenced by several factors such as age, gender, sleep, nutrition, training history, recovery, as well as by environmental, social, and psychological factors (Kyröläinen et al., 2018). In the military environment, prolonged physical activity with external load, sleep deprivation, and negative fluid and nutrition balance are also obstacles that one must overcome in optimizing physical performance gains (Henning, Park, & Kim, 2011; Nindl et al., 2007). It has been shown that these training and environmental factors can lead to overreaching or even overtraining leading to increased risk of injury occurrence (Booth, Probert, Forbes-Ewan, & Coad, 2006). It is important to consider these factors when planning and implementing training programs for warfighters.

Currently, military duties require more physical fitness than in the past (Friedl et al., 2015; Knapik, Reynolds, & Harman, 2004). In recruits, military training involves a high amount of physical activity, which can be a new experience for most of the recruits. Therefore, it is important to start physical training during basic training (8 weeks) and in fitness matched groups to ensure that all recruits are able to improve their physical performance in the beginning of their service and also to build a solid platform to increased physical training after the basic training period (Hofstetter, Mäder, & Wyss, 2012; Santtila, Pihlainen, Viskari, & Kyröläinen, 2015; Sporis et al., 2014). Despite technological advances and lighter material, the weight carried by a warfighter has also increased. This is mainly due to the requirement to carry more pieces of equipment which are also heavier, for example, body armors and radios (Drain, Billing, Neesham-Smith, & Aisbett, 2016; Kraemer & Ratamess, 2005). In addition, the type of tasks a soldier needs to perform has moved towards more explosive type of tasks, for example, close quarters combat. Thus, higher physical requirements combined with the decrease in physical fitness have led to a situation where physical training has to be carefully and systematically tailored to meet the needs of the basic training. When designing a training plan for warfighters, it is important to consider the factors emphasizing the task requirements or performance goals (Nindl et al., 2013). A need for progression, variation, and specificity in training stimulus are the most important factors when considering the development of maximal or explosive strength and maximal aerobic capacity (Friedl et al., 2015; Kyröläinen et al., 2018). Daily military training itself can be short of variety, which may not improve physical performance in an optimal way. For professional warfighters, it is important to have training programs that lead them to reach, as well as to maintain the required level for physical performance (Klien, Hjelvang, Dall, Kruse, & Nordsborg, 2015).

Prolonged military field training has been shown to lead to a decrease in maximal strength and power (Nindl et al., 2002, 2007). Hypertrophic strength training can improve muscular strength by increasing muscle size, while during maximal and explosive strength training gains in strength and power are obtained to a greater extent also by neural factors, for example, increased activation of the agonist muscles (Häkkinen, 1994; Häkkinen et al., 1998). The military environment creates a special platform for strength development because endurance training is always integrated to warfighters' training programs (Friedl et al., 2015). The effects of military task-specific training on strength and maximal short duration anaerobic performance of a warfighter has not been investigated. Load carriage studies have shown that added strength training can increase the warfighters' capability to carry load (Knapik et al., 2004). Whether the same result can be obtained by task-specific training is unknown, which includes exercises that the soldiers would do in the actual battlefield situation (e.g., loaded sprinting, casualty drags, crawling, climbing or jumping over obstacles, and carrying different objects), is unknown.

Measurement of serum hormone concentrations can be useful in evaluating the effects of different training programs and physiological changes in soldiers' bodies. Changes in serum hormone concentrations have been found to take place during military field training (MFT). Serum testosterone (TES) is responsible for promoting muscle and bone mass, and has been reported to decrease during MFT by 24%–49% (Alemany et al., 2008; Nindl et al., 2006). Cortisol is released in response to psychological and physical stress, and it has widely been measured during MFT. It has been shown to increase during MFT by 32% (Friedl et al., 2000; Nindl et al., 2007). The TES/COR ratio has been shown to decrease after a week of overreaching endurance training (Adlercreutz et al., 1986) and at the end of a prolonged strength training period (Häkkinen, Pakarinen, Alen, & Komi, 1985), as well as during an intensive high-volume strength training week in weightlifters (Häkkinen, Pakarinen, Alen, Kauhanen, &

Komi, 1988). Similar observations have been made in warfighters (Booth et al., 2006; Fortes et al., 2011). The TES/COR ratio has also been used to study strength training and total physical load in conscripts (Santtila, Kyröläinen, & Häkkinen, 2009; Tanskanen et al., 2011). Added strength training during basic military training (BMT) can also lead to an increase in cortisol concentrations (Santtila et al., 2009). Sex hormone-binding globulin (SHBG) concentration can increase during 8 weeks of BMT (Nindl et al., 2007), and SHBG is known to inhibit the function of TES. Insulin-like growth factor-1 (IGF-1) has been shown to serve as a potential biomarker for health, fitness, and training status (Nindl et al., 2017). Physical strain and energy deficit have been shown to increase IGF-1 concentration during MFT (Friedl et al., 2015; Nindl et al., 2002; Vaara, Kokko, Isoranta, & Kyröläinen, 2015). An 8-week military strength training program can result in an initial increase in IGF-1 concentration, but these values have then decreased back to existing prevalues after training and consequently no increase between the PRE and POST values have been observed (Nindl et al., 2017).

The purpose of this study was to investigate the effects of two different training programs on strength and power performance and serum hormone concentrations in conscripts during 12 weeks implemented after the basic training period. It was hypothesized that task-specific training is, at least, as good as strength training, and both of them would improve strength and power performance more than normal military physical training.

2 | METHODS

2.1 | Subjects

In all, 104 male conscripts, who were conducting their mandatory military service and had completed their basic training successfully, volunteered as participants for the present study. In the beginning, the three groups had from 33 to 38 participants each, but only 51 of the total number of subjects completed all the measurements during the 12-week study period (Table 1) leaving the following number of participants who were included in the study as follows: TS ($n = 19$), ST ($n = 20$), and CON ($n = 12$). Reasons for the missed measurements were their overlap with the military training schedule and health-related problems such as flu or musculoskeletal injury that prevented some participants to either attend the MID or POST testing sessions, thus their data were removed from the analysis. The participants were 18- to 22-year-old male conscripts. The mean (±*SD*) age was 20 ± 1 years, height 180 ± 6 cm, body mass 72.4 ± 8.8 kg, and body mass index 22.3 ± 2.2 kg/m^2. The present study was conducted according to the provisions of the Declaration of Helsinki and

TABLE 1 Mean (±*SD*) age, height, body mass, and BMI in the study groups

Variable	Task specific ($n = 19$)	Strength ($n = 20$)	Control ($n = 12$)
Age (yrs.)	19.5 (0.8)	19.5 (0.7)	19.6 (0.8)
Height (cm)	180.1 (6.6)	181.5 (6.0)	179.5 (5.4)
Body mass (kg)	74.6 (10.4)	72.3 (7.5)	70.3 (10.2)
BMI (kg·m^{-2})	23.0 (2.2)	22.0 (1.7)	22.4 (2.9)

Abbreviation: BMI, body mass index.

ethical approval was granted by the Ethical Committee of the University of Jyväskylä. The study was also approved by the Finnish Defence Forces. All the conscripts were informed of the experimental design, and the benefits and possible risks that could be associated with the study prior to signing an informed consent document to participate in the study.

2.2 | Experimental design

A 12-week training period was implemented after the basic training period. Body composition, blood samples, and physical performance measurements were repeated three times during the study, in the 10th week (PRE), 16th (MID), and in the 21st week (POST) of their service. On the test days, body composition was measured and blood samples were taken before breakfast. After the breakfast, a series of physical performance tests were performed.

Training programs were designed to be easy to perform during normal weekly physical training. The subjects were all from the same infantry company, and they were divided into three training groups as follows: soldier task-specific training group (TS), strength-training group (ST), and control group (CON). Each group was randomly selected platoon from the infantry company and each platoon had a total of 18 training sessions during the 12-week study with their instructor according to the specific training program. There were some weeks when the conscripts were carrying out MFT when normal physical conditioning was not possible to perform. The number of training sessions varied from one to three per week. Training was regular and periodized, especially, during the first part of the study but during the second part, several field-training weeks made the conditioning more challenging.

2.3 | Measurements

Physical testing took place three times during the study (PRE, MID, and POST). Baseline (PRE) testing was made on week 1, MID testing on week 7, and POST testing on week 12 of the study. The testing started in the morning with body composition measurements and blood samples. After the breakfast, the subjects performed muscular power, strength, and muscle endurance tests. Every training group completed their tests during the same day, and the testing was conducted using the same protocol in all measurement points.

2.3.1 | Body composition

Body composition characteristics were measured in the morning after an overnight fast between 06:00 and 07:00. The subjects were instructed not to eat anything after their evening meal, which was around 19:00, but they were allowed to drink normally. Body mass (BM), skeletal muscle mass (SMM), fat mass (FM), and fat percentage (FAT%) were measured by using the segmental multi-frequency bioimpedance analysis assessment (BIA) (InBody 720, Biospace Co Ltd, Seoul, South Korea). The BIA estimates of body composition have shown to highly correlate with the dual-energy X-ray absorptiometry (DXA) method ($r = 0.82$–0.95) (Sillanpää et al., 2014).

2.3.2 | Serum hormone concentrations

Venous blood samples were drawn three times into Vacutainer® gel tube from the antecubital vein after an overnight fast between 06:30 and 07:30 to analyze serum concentrations of testosterone (TES), cortisol (COR), sex hormone binding globulin (SHBG), IGF-1, and insulin-like growth factor binding protein-3 (IGFBP-3) (Siemens Immulite 2000 XPI, Siemens Healthcare, USA). The sensitivity and interassay coefficients of variance for these assays were 0.5 nmol/l and 8.2% for TES, 5.5 nmol/l and 7.9% for COR, 0.02 nmol/l and 5.2% for SHBG, 2.6 nmol/l and 7.1% for IGF-1, and 0.3 nmol/l and 8.4% for IGFBP-3. The samples were centrifuged (Megafire 1.0 R Heraeus, DJB Lab Care, Germany) after 30 min at 2000 g for 10 min, frozen, and transported to the laboratory for later analysis.

2.3.3 | Strength and power performance

All participants were familiarized with all the assessments either due to previous training or before the measurements. Maximal isometric force of the upper (MVCupper) and lower (MVClower) extremities were measured bilaterally in a sitting position. The measurements were conducted using an electromechanical dynamometer manufactured by the University of Jyväskylä, Jyväskylä, Finland. The knee and hip angles were set to 107° and 110° (Häkkinen et al., 1998) in the horizontal leg press position. The knee angle was measured using the trochanter major and the lateral malleolus as reference points. Subjects were told to ensure that they keep contact with the seat and the backrest during the performance. During the measurements of upper extremities, the equipment was adjusted for each subject to their sitting position with their feet flat on the floor, the arms were parallel to the floor, and the elbow angle was 90°. The test was performed by pushing the bar horizontally. The subjects were given one trial attempt before the two actual test trials were conducted for both leg press and bench press with a minimum of 60 s for recovery. In both tests, the subjects were instructed to produce maximal force as fast as possible. During all trials, the testing personnel encouraged them vocally during the maximal effort. The best performances with regard to maximal force output in both tests were selected for further analysis.

Countermovement jump (CMJ) was performed on a contact mat (Newtest, Oulu, Finland). Subjects were instructed to keep their arms on their hips while performing the jump. Subjects started their maximal vertical jumps from a standing position, hands on their hips. The lowest knee angle was instructed to be 90°. All the subjects had three jump attempts. Flight time from contact to contact was used to calculate the jumping height for each jump (Bosco, Luhtanen, & Komi, 1983).

A 6-s maximal anaerobic power cycle ergometer test (Wattbike Ltd) was used to measure maximal power in the lower extremities. The 6-s test has a seated stationary start with the dominant leg initiating the first down-stroke. Before the test, each subject's weight was inserted into the test bikes computer and air and magnetic resistance were set accordingly. The test started following a 5-s countdown followed by verbal command. The completion of the test was indicated also with another verbal command (Herbert, Sculthorpe, Baker, & Grace, 2015).

Standing long jump (SLJ) was used to measure explosive force production of the lower extremities (Bosco et al., 1983). The jumps were performed on a 10-millimeter-thick plastic mattress designed for the purpose (Fysioline Co). Conscripts were given instructions of a proper technique, and two to three warm-up trials before the actual three test attempts. The jumps were performed from a standing position, feet at pelvis to shoulder width. Take off was assisted by extension of the hip and swinging of the arms. The landing was performed bilaterally and falling backwards led to the disqualification of the attempt. The result of the best jump was measured in centimeters from the shortest distance from the landing point to the starting line.

Muscle endurance capacity of the trunk and upper extremities was measured using sit-up and push-ups tests. A test supervisor showed the proper technique for both performances before the tests. Sit-ups were used to measure abdominal and hip flexor performance (Viljanen, Viitasalo, & Kujala, 1991). In the starting position, the conscript laid on his back, while the legs were supported from the ankles by an assistant. The knee angle was 90°, elbows pointing upwards, and fingers crossed behind the head. A successful repetition was credited when the conscript lifted his upper body from the starting position and brought elbows to the knee-level. The result was the number of successful repetitions during 60 s. Push-ups were used to measure performance of the arm and shoulder extensor muscles (ACSM, 2000). Before taking a starting position, the conscript laid face down on the floor, feet parallel at pelvis to shoulder width, and hands positioned so that the thumbs could reach the shoulders while other fingers pointing forward. Before the initiation of the test, the conscripts were instructed to extend their arms to the starting position and keep the feet, trunk, and shoulders in the same line throughout the test. One successful repetition was counted when the soldier lowered his torso by flexing arms to an elbow angle of 90° and returned to the starting position by extending his arms. The result was the number of successful repetitions during 60 s.

2.4 | Training protocols

The total amount of instructed physical training sessions performed by the subjects was 12 during the first 6 weeks and 6 during the latter 6 weeks of the study (Table 2). They also conducted their normal military training every day, which consisted of road marches, shooting exercises, and other task-specific exercises. Variation of the instructed physical training program was due to MFTs that their schedule had. During those weeks, the conscripts were not able to do any extra physical training. When planning the training program for our study, we tried to consider these factors, as well as possible. The most demanding physical training sessions were done during the lightest military training weeks. All the groups participated in the instructed physical training, but the content of training varied between the groups. All groups performed 10 min active warm-up consisting of muscular activation before starting the actual exercise. The total length of one training session was 60 min in all groups.

2.4.1 | Task-Specific group (TS)

The task-specific group performed basic infantry-based exercises with the full combat gear (27 kg), such as sprints, crawling, casualty drag, and climbing over obstacles. The exercises focused on anaerobic or speed. The TS exercises performed with speed emphasis were conducted for 6 s, performed with maximal effort and a 2-min recovery time between the sets. The TS exercises performed with anaerobic emphasis were conducted for 30–60 s for each repetition, with 75%–90% of maximal effort and a 1-min recovery time between the sets (Table 2).

TABLE 2 Design of the training protocols in the study groups

Session	Task-specific group			Strength group			Control group		
	1	2	3	1	2	3	1	2	3
Week 1	PRE tests			PRE tests			PRE tests		
Week 2	2x3x6s	2x3x30s	3x6s; 3x30s	4x3x15x10–30%	4x3x15x10–30%	4x3x10x40–60%	Military PE	Military PE	Military PE
Week 3	2x4x6s	2x4x30s	4x6s; 4x30s	4x3x10x40–60%	BWT x 5 exercises	BWT x 5 exercises	Military PE	Military PE	Military PE
Week 4	3x3x6s	3x3x45s	4x6s; 4x45s	6x3x6x20–40%	4x3x3–5x70–90%	4x3x8x50–75%	Military PE	Military PE	Military PE
Week 5	3x3x6s	3x3x45s	4x6s; 4x45s	6x3x6x20–40%	4x3x3–5x70–90%	4x3x12x50–75%	Military PE	Military PE	Military PE
Week 6	Military field training			Military field training			Military field training		
Week 7	MID tests			MID TESTS			MID tests		
Week 8	3x3x6s	4x45s	3x3x60s	BWT x 5 exercises	BWT x 5 exercises	4x3x3–5x70–90%	Military PE	Military PE	Military PE
Week 9	Military field training			Military field training			Military field training		
Week 10	3x4x6s	3x6s; 3x60s	3x4x6s	5x3x4–6x70–90%	6x3x4–6x20–40%	5x2x4–6x70–90%	Military PE	Military PE	Military PE
Week 11	Military field training			Military field training			Military field training		
Week 12	POST tests			POST tests			POST tests		

2.4.2 | Strength group (ST)

The strength group had a nonlinear training program, which included muscular endurance, hypertrophic, and maximal strength and power training. Strength training started with lower intensity and higher repetitions (10–15 repetitions with 10%–60% of 1RM), but soon turned into hypertrophic (8–12 repetitions with 50%–75% of 1RM), maximal strength (3–6 repetitions with 70%–90% of 1RM) or power (4–6 repetitions with 20%–40% of 1RM) workouts (Table 2). There were four to five different exercises (e.g., squat, deadlift, bench press and different push, and pull exercises for upper body) in each session and three to six sets per each exercise.

2.4.3 | Control group (CON)

The control group trained according to the normal Finnish military physical education guidelines, which included muscular endurance training, ball games, and endurance training. A normal training session included, for example, circuit training with body weight, running with constant pace or playing basketball, football, or floorball. The total amount of their training was the same compared to the other groups (Table 2).

2.5 | Statistical analysis

The data for the present study were analyzed using SPSS Statistics 24 (IBM SPSS 24.0 Chicago, Illinois). All data were checked for normality. For calculating means, 95% confidence intervals, standard deviations (±*SD*), and Pearson product moment correlation coefficients conventional statistics were used. Probability adjusted *t* tests were used for pairwise comparisons when appropriate. The effect size was calculated as the mean difference between the PRE, MID, and POST measurement values divided by the standard deviation of the values (0.2 = small; 0,5 = medium; 0,8 = large effect (Cohen, 1988). A general linear model, with repeated measures ANOVA with group as a fixed factor, was used to analyze time * group interaction and the differences between the different measuring points. Bivariate correlation was used to assess associations between the changes in time. The $p < .05$ criterion was used for establishing the statistical significance.

3 | RESULTS

3.1 | Body composition

Significant increases from PRE to POST and MID to POST were found in body mass in ST (1.5 ± 2.8% and 0.8 ± 1.7%;

TABLE 3 Mean (±*SD*) values of body composition in the study groups

		PRE		MID		POST		|Effect size|		
	Group	Mean (±*SD*)	95% CI	Mean (±*SD*)	95% CI	Mean (±*SD*)	95% CI	1 versus 2	2 versus 3	1 versus 3
BM (kg)	TS	74.6 ± 10.4	69.6; 79.6	74.3 ± 9.7	69.7; 79.0	74.8 ± 9.4	70.2; 79.3	0.03	0.05	0.02
	ST	72.3 ± 7.7	68.5; 76.0	72.7 ± 7.5	69.1; 76.3	73.3 ± 7.9 $^{\#, \$}$	69.5; 77.1	0.05	0.08	0.13
	CON	70.3 ± 10.2	63.8; 76.7	69.8 ± 9.0	64.1; 75.5	70.1 ± 8.3	64.8; 75.3	0.05	0.03	0.02
SMM (kg)	TS	36.7 ± 4.8	34.4; 39.0	37.3 ± 4.7 *	35.0; 39.6	37.1 ± 4.8 $^{\#}$	34.8; 39.4	0.12	0.04	0.08
	ST	37.0 ± 4.1	35.1; 38.9	37.4 ± 4.0 *	35.5; 39.3	37.5 ± 4.1	35.5; 39.4	0.10	0.02	0.12
	CON	34.7 ± 4.3	31.9; 37.4	34.8 ± 4.4	32.0; 37.5	34.8 ± 4.5	31.9; 37.6	0.02	0.00	0.02
FM (kg)	TS	10.1 ± 4.6	7.9; 12.2	8.9 ± 3.7 *	7.1; 10.7	9.7 ± 3.7 $^{\$\$}$	7.9; 11.5	0.28	0.21	0.09
	ST	7.3 ± 2.8	6.0; 8.6	7.2 ± 2.9	5.9; 8.6	7.9 ± 3.1 $^{\$\$\$}$	6.4; 9.3	0.03	0.23	0.20
	CON	9.2 ± 5.1	6.0; 12.4	8.7 ± 4.3	6.0; 11.4	8.9 ± 3.7	6.6; 11.3	0.10	0.05	0.07
FAT%	TS	13.3 ± 4.7	11.0; 15.5	11.9 ± 3.9 *	10.0; 13.8	12.9 ± 4.1 $^{\$\$}$	10.9; 14.9	0.32	0.24	0.09
	ST	10.1 ± 3.5	8.4; 11.7	9.9 ± 3.5	8.2; 11.5	10.6 ± 3.6 $^{\$\$\$}$	8.9; 12.3	0.06	0.19	0.14
	CON	12.6 ± 5.7	9.0; 16.3	12.3 ± 5.4	8.9; 15.7	12.7 ± 4.6	9.7; 15.6	0.05	0.08	0.02

Abbreviations: BM, body mass; SMM, skeletal muscle mass; FM, fat mass; FAT%, fat percentage; TS, task specific; ST, strength; CON, control. * = PRE to MID values * = $p<0.05$; # = PRE to POST values, # = p<0.05, MID to POST values \$ = $p<0.05$, \$\$ = $p<0.01$, \$\$\$ $p<0.001$

Table 3). In addition, significant increases were found in SMM between the PRE and MID measurement points in the TS (1.7 ± 3.0%) and ST (1.0 ± 1.9%) groups. A significant drop in FM was observed in the TS (−9.5 ± 13.5%) group between the PRE and MID measurements, but FM (11.1 ± 21.7%) recovered almost back to the PRE values from the MID to POST measurements. No significant differences were observed between the groups in any measurement points.

3.2 | Strength and power performance

In the strength and power performances most of the significant increases took place in the TS and ST groups, both during the first part and after the entire experimental training period (Table 4). Isometric leg press force increased significantly by 7.9 ± 12.2% ($p < .05$) for TS and by 7.1 ± 12.6% ($p < .05$) for ST between the PRE and MID measurements. A significant increase in leg press force was also observed in TS 8.1 ± 12.4% ($p < .05$) and ST 12.3 ± 15.3% ($p < .01$) between the PRE and POST measurements. Isometric horizontal bench press force increased significantly by 4.7 ± 6.8% ($p < .01$) between the PRE and MID and by 7.1 ± 7.0% ($p < .01$) between the PRE and POST measurements. Maximal power in the 6-s cycling test increased significantly between PRE and MID by 4.4 ± 6.9% ($p < .05$) in TS and 4.1 ± 4.8% ($p < .01$) in ST, as well as between the PRE and POST measurements in TS 6.0 ± 6.3% ($p < .05$), in ST 4.1 ± 5.3% ($p < .01$) and in CON 5.3 ± 5.5% ($p < .01$). In push-ups, there were significant increases between the PRE and MID measurements in TS 26.5 ± 33.4 ($p < .01$) and in ST 14.0 ± 13.1 ($p < .05$) groups. Between PRE and POST, the CON group improved significantly 31.0 ± 26.9 ($p < .01$) its push-ups performance. No significant differences were observed between the groups in the PRE measurements. The CON group differed significantly from the TS and ST groups in lower body strength in the MID and POST measurements and also in standing long jump in the POST measurement point.

3.3 | Changes in serum hormone concentrations.

Serum TES concentration increased significantly in TS between the PRE and MID (16.8 ± 33.9%) and PRE and POST (11.2 ± 16.7%) measurements (Figure 1). Serum COR concentrations decreased in TS between the MID and POST (−7.8 ± 10.9%) and PRE and POST (−11.0 ± 14.3%) measurements. In CON, a decrease in COR concentration was found between PRE and POST (−16.3 ± 14.8%). Serum SHBG concentrations increased both in the TS and ST groups between PRE and MID (18.2 ± 19.6% for TS and 24.9 ± 30.3 for ST) and between PRE and POST (11.0 ± 17.4% for TS and 23.5 ± 38.2% for ST). In CON SHBG first increased significantly (20.0 ± 32.9%) between PRE and MID and then decreased significantly (−5.8 ± 25.2%) between MID and POST. IGF-1 concentration decreased in TS between MID and POST (−11.1 ± 15.1%) and PRE and POST (−7.7 ± 16.0%). The CON group showed significant increases in IGF-1 between PRE and MID (10.5 ± 10.9%). IGFBP-3 concentration increased significantly in ST between PRE and MID (9.8 ± 14.4%) and in CON between PRE and POST (29.5 ± 46.2%). The TES/COR-ratio increased significantly in all groups between PRE and MID and PRE and POST, while a significant change was only observed between PRE and POST in CON.

4 | DISCUSSION

The main objective of this study was to find out how different physical training modes influence warfighter's strength and power performances and serum hormone concentrations during the 12-week conscript training period. All three groups conducted the same volume of physical training, and only the content of the training mode varied between the groups. The main findings showed that both task-specific and strength training programs increased maximal strength and power performances to a greater degree compared to normal military physical training. The findings support our hypothesis of the need for strength and power related training in soldiers. Daily military training may also have a great impact on the development of different physical characteristics. In the present study, physical training was highly compromised by military field training and only minor improvements took place in the latter part of the study.

In the previous study with conscripts (Santtila, Häkkinen, Karavirta, & Kyröläinen, 2008), it has been shown that basic military training leads to increases in physical performance including both endurance and strength capability. Similar results have been reported also during US Army Basic Training (Hendrickson et al., 2010; Knapik et al., 2001). Increases in strength and power have also been reported in previously trained warfighters (Abt et al., 2016; Lester et al., 2014; Solberg et al., 2015). The present TS and ST groups showed the highest increase in strength and power measurements, both between the PRE and MID and PRE and POST measurement points. The training was not interrupted by tactical field training that much during the first weeks of the study as during the last weeks. The plateau observed between the MID and POST measurement points was likely due to the decreased amount of controlled training and the increased amount of field training. Low volume of training sessions (1 to 2) per week may not be enough to lead to large changes in body composition or

TABLE 4 Mean (±*SD*) strength and power performance values in the study groups

	Group	PRE		MID		POST		|Effect size|		
		Mean (±*SD*)	95% CI	Mean (±*SD*)	95% CI	Mean (±*SD*)	95% CI	1 versus 2	2 versus 3	1 versus 3
CMJ (cm)	TS	30 ± 5	27; 32	29 ± 5	27; 31	31 ± 4**, ###	29; 33	0.20	0.43	0.22
	ST	32 ± 6	29; 35	33 ± 5	30; 35	34 ± 5	32; 36	0.18	0.20	0.35
	CON	31 ± 6	28; 35	30 ± 7*	25; 34	31 ± 6	28; 35	0.15	0.15	0.00
Power Max (w)	TS	1,038 ± 153	964; 1,112	1,075 ± 152*	1,002; 1,149	1,096 ± 141*, ##	1,028; 1,164	0.24	0.14	0.39
	ST	1,070 ± 112	1,012; 1,119	1,119 ± 120**	1,054; 1,159	1,120 ± 126**	1,051; 1,165	0.41	0.01	0.41
	CON	952 ± 104	896; 1,040	992 ± 136	905; 1,078	1,017 ± 139**	928; 1,105	0.32	0.18	0.51
Upper body strength (kg)	TS	79 ± 16	71; 86	77 ± 14	70; 83	80 ± 13###	74; 87	0.13	0.22	0.07
	ST	77 ± 15	70; 84	82 ± 16**	72; 88	82 ± 17**	74; 90	0.32	0.00	0.31
	CON	72 ± 15	64; 83	73 ± 12	70; 83	76 ± 15	65; 86	0.07	0.21	0.26
Lower body strength (kg)	TS	240 ± 46	219; 263	255 ± 49*	232; 279	263 ± 48**	240; 286	0.32	0.16	0.48
	ST	227 ± 46	205; 248	240 ± 37*	222; 257	240 ± 38*	222; 258	0.31	0.00	0.30
	CON	214 ± 51	182; 247	220 ± 61 µ	181; 259	222 ± 60 µ	184; 261	0.10	0.03	0.14
Standing long jump (cm)	TS	216 ± 25	204; 228	215 ± 21	205; 225	216 ± 21	205; 226	0.04	0.05	0.00
	ST	228 ± 17	220; 237	228 ± 18	218; 233	229 ± 17	220; 235	0.00	0.06	0.06
	CON	214 ± 32	194; 234	210 ± 28	192; 228	210 ± 31µ	190; 229	0.13	0.00	0.12
Sit-ups (reps/min)	TS	41 ± 10	36; 45	42 ± 9	37; 46	40 ± 12	34; 46	0.10	0.18	0.09
	ST	44 ± 9	39; 48	45 ± 8	40; 48	45 ± 9	40; 48	0.12	0.00	0.11
	CON	41 ± 7	36; 46	43 ± 8	38; 48	42 ± 7	37; 47	0.26	0.13	0.14
Push-Ups (reps/min)	TS	34 ± 13	28; 40	40 ± 14**	33; 47	38 ± 15	31; 45	0.43	0.13	0.28
	ST	38 ± 12	32; 44	43 ± 13*	36; 48	41 ± 14	34; 47	0.39	0.23	0.15
	CON	35 ± 14	25; 45	41 ± 15	29; 50	44 ± 16**	33; 54	0.40	0.19	0.58

Abbreviations: CMJ, counter measurement jump; Power max, maximal 6 s power cycling; Upper body strength in maximal isometric action; Lower body strength in maximal isometric action; TS, task specific; ST, strength; CON, control. * = PRE to MID values *= $p<0.05$; # = PRE to POST values, # = $p<0.05$, ## = $p<0.01$, ### $p<0.001$, MID to POST values § = $p<0.05$, §§ = $p<0.01$, §§§ $p<0.001$; between the groups, µ = $p < 0.05$

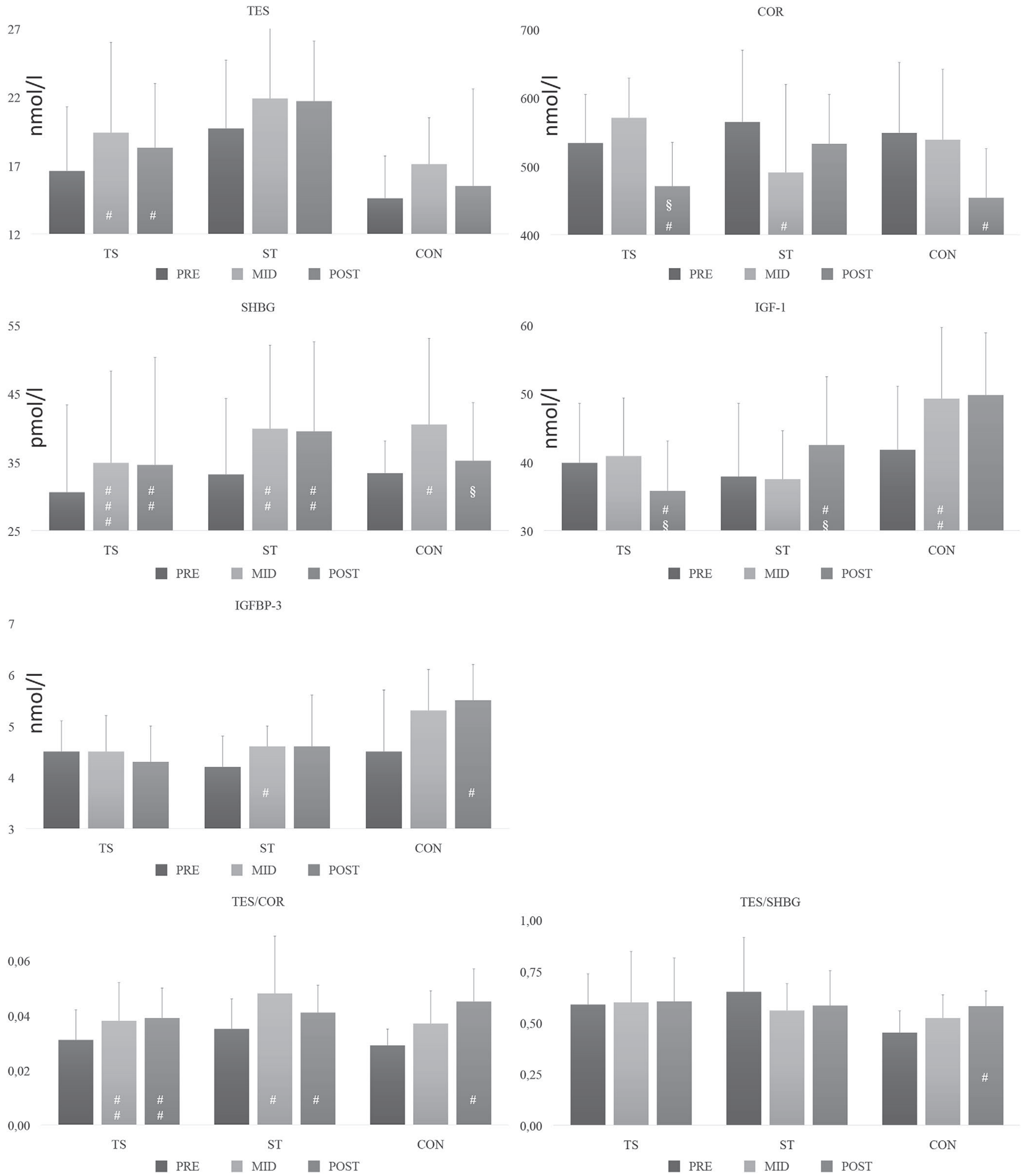

FIGURE 1 Mean (±SD) serum hormonal concentrations in the groups. COR, cortisol; CON, control; IGF-1 insulin-like growth factor 1; IGFBP-3, insulin-like growth factor binding protein 3; SHBG, sex-hormone binding globulin; ST, strength; TES, testosterone; TES/COR, testosterone – cortisol ratio; TES/SHBG, testosterone – sex-hormone binding globulin; TS, task specific. Within the groups; #=$p < .05$, ##=$p < .01$, ###=$p < .001$, compared to PRE value; §=$p < .05$, compared to MID value.

strength/power gains. In the present study, the most improvement was observed during the first 6 weeks when the amount of training sessions was 2–3 per week. During the last 6 weeks not much difference between the groups was observed, because of the high amount of military field training that made it difficult to carry out physical training as planned. The present CON group had also some improvements in strength and power performances, but not as much as in the TS and ST groups. It is also possible that the greater volume of endurance training in the CON group might have also interfered with their strength and power development compared to the TS and ST groups. Due to the present study design, we could not evaluate possible changes in maximal aerobic performance in any of the present groups. The similarity of the gains in the ST and TS groups were probably mostly because of the increased training stimuli for upper and lower body muscles. The training in the TS group with extra weight was similar to that of the weight training in the ST group with regard to the intensity and duration.

In previous studies, decreases in serum hormonal concentrations have been reported as a response to physical exertion combined with energy and sleep deprivation (Alemany et al., 2008; Friedl et al., 2000; Kyröläinen et al., 2008; Nindl et al., 2007; Richmond et al., 2014). Intensive field training can lead to drastic declines in total TES and IGF-1 concentrations (Nindl et al., 2007). Friedl et al. (2000) showed that significant decreases in TES and IGF-1 concentrations occurred after the 8-week military field training period with increases in SHBG and COR concentrations. The present study did not find such drastic changes. The TES and IGF-1 levels were either unaltered or increased during the study. SHBG seemed to increase to some extent, and COR remained at the same level or even decreased during the study. These results suggest that the conscripts were not physically overtrained during the present study. Most of the changes in the measured serum concentrations may refer to an improved anabolic state. Therefore, it seems that the conscripts were not overtrained during their latter part of their conscript service, although the increases in the present strength and power performance variables remained minor between the MID and POST measurements.

Total TES concentration has been shown to lead to an acute increase after resistance exercise in men (Hakkinen & Pakarinen, 1993; Kraemer & Ratamess, 2005). Tremblay, Copeland, and Van Helder (2004) reported that the acute elevation in TES was greater in strength trained men than in endurance trained. This could suggest that strength training could have beneficial periodical (Häkkinen, Pakarinen, Alen, Kauhanen, & Komi, 1987; Häkkinen et al., 1985, 1988) adaptations in TES as observed in strength trained athletes (Häkkinen et al., 1987, 1988). In the present study, the increases in TES took place during the first 6 weeks but this was not replicated during the last 6 weeks of the intervention (Figure 1). Concurrent military training could have contributed to the present findings. Similar acute increases have been found in SHBG concentrations, but not in resting values in longer-term studies (Kraemer & Ratamess, 2005). There was a significant increase in SHBG in all the groups from PRE to MID in the present study but from MID to POST, SHBG concentrations remained statistically unaltered. COR concentrations have been shown to increase acutely, but no consistent pattern has been found in long-term training stress (Kraemer & Ratamess, 2005). COR concentrations decreased in all groups from the PRE to POST measurements. This resulted in a rise in the TES/COR-ratio, which could indicate that the conscripts were unlikely overtrained. Resting IGF-1 concentration has been shown to be higher in resistance-trained than untrained men. It appears that the volume and training intensity are important factors for chronic IGF-1 adaptations (Kraemer & Ratamess, 2005). In the present study, the increases in IGF-1 were observed in the CON and ST groups. The same was found also with regard to IGFBP-3 concentrations. These findings indicate that different types of concurrent training can elevate anabolic hormone concentrations and contribute to an increase in muscle mass as observed in the present TS and ST groups. It is important to have intensive strength training during military training, while attempting to create both acute and chronic positive hormonal changes, as well as increased maximal strength and power of the trained muscles.

During the present study the conscripts were completing their military service, which involves a high volume of low aerobic type of activity with constant load carriage. Because of physical and tactical demands of their training, this type of activity is unavoidable. The regular day-to-day military training schedule did not allow most of the time for periods of rest after field exercises or physical training activities. That is why, it is likely that this concurrent type of training had at least some effect on the physical performance of the subjects, but the purpose was to determine what kind of training might be most beneficial during normal military service. In addition, MFT may have created inconsistent training responses during the second part of the study. Also, the MID and POST measurements were done after the MFT week due to the tight training schedule. The present study was limited by the small number of subjects per group, which may have reduced the generalizability of the present findings. The training program for the ST and TS groups were quite different from that taking place during the basic training. All exercises were familiar for most of the subjects, but better familiarization might lead to better results in the future. Also, the effectiveness of military task-specific training that TS group did should be studied more in detail in the future. We had a task-specific military simulation test in our measurements, but we did not include those results as we wanted to concentrate on changes in body composition, strength/power, and hormonal measurements. More periodization between military training and physical training is needed in the future to achieve better enhancement of physical performance. In addition, the future research should follow the development of strength and power throughout the conscript service. This would help to develop more optimal long-term training program for strength and power in a military environment.

In conclusion, training in the TS and ST groups led to greater improvements in muscle strength and power than training in the CON group. Especially, the increases in lower body strength and power, as well as in upper body strength were greater in the TS and ST groups. These findings are important for warfighter performance. In previous studies, the need for the high level of strength has been found to be vital to warfighter (Friedl et al., 2015; Kraemer & Szivak, 2012). Daily military training may consist too much of low-intensity aerobic work which does not lead to the increase in warfighters' strength.

5 | CONCLUSION

By creating variation in the training content during the conscript service, it is possible to make improvements in different components of the physical performance capacity, especially in strength and power, which can be translated to improvement in common tactical movements (i.e., marching, load carriage, and fire and movement drills). With structured, regular, and controlled physical training, the impact on conscripts' physical performance would be greater than with the current military physical training. However, successful strength and conditioning program for conscripts cannot be built without taking into account the fracture nature of training caused by military-specific training requirements. It is important in the future that the leadership prioritizes quality-controlled physical training and supports necessary changes. Strength and task-specific training can lead to improvements in the battlefield, reduce the risk of overtraining, and prevent injuries caused by excessive running and loaded marching during the traditional military training. Furthermore, in the future, it is important to study the effects of ST and TS after basic training for optimizing the periodization, duration, intensity, and frequency of strength and power training on the development of the physical performance capacity required for the battlefield.

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IV

EFFECTS OF TASK-SPECIFIC AND STRENGTH TRAINING ON SIMULATED MILITARY TASK PERFORMANCE IN SOLDIERS

by

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Effects of Task-Specific and Strength Training on Simulated Military Task Performance in Soldiers

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Abstract: A soldier's occupational physical task requirements are diverse and varied. However, the type of physical training that most effectively improves soldiers' occupational task requirements has not been studied previously. The purpose of this study was to determine the important strength characteristics for soldiers during a repeated simulated military task course, and the type of training that may be effective to improve these abilities during a specialized military training period. Forty-two (n = 42) soldiers participated in the study. They were divided into three training groups; a soldier task-specific training group (TSG, n = 17), a strength training group (STG, n = 15), and a control group (CON, n = 10). Participants were measured before (PRE), middle (MID) and after (POST) the 12-week training intervention for strength performance and simulated military task test. Simulated military task performance improved significantly in TSG and STG between the PRE and MID measurements (from 9.4 to 15.7%). TSG and STG improved in various spilt times, especially in strength tasks; casualty drag (from 8.3 to 13.6%) and kettlebell carry (from 13.2 to 22.4%) between the PRE and MID measurements. The present study showed that both the training of TSG and STG were more effective than the training of CON (control group) in terms of improving the performance in the repeated simulated military task course. The present study showed that training of TSG was as effective as STG to improve repeated simulated military task course time. Therefore, an optimal training combination should include high-intensity simulated military task field training and strength training programmed with consideration of the military training phase and environmental possibilities.

Keywords: neuromuscular performance; strength training; task-specific; occupational test; military; soldier

1. Introduction

Common occupational physical tasks for soldiers can include patrolling long distances in different terrains, carrying and lifting objects with variable weight, and performing explosive movements in the battlefield [1]. All these requirements create complexity for constructing physical training programs for soldiers. In all, various factors including sex, age, physical training history, nutrition, recovery, and sleep, in addition to psychological, environmental, and social aspects can significantly influence physical training adaptations [2]. Moreover, optimizing a soldier's performance in military environments is constantly challenged by external stress factors including carrying loads of various weights, sleep deprivation, extended physical activity, negative fluid and energy balance, and continuous readiness [3–5]. These stressors have been shown to cause disruptions in hormonal balance [6–9], leading to reduced physical and cognitive performance [3,10–13], prolonged recovery times [14], and increased susceptibility to infections [15]. Therefore, training load combined with these external stress factors can lead to compromised training adaptations, overreaching or even overtraining, in addition to increased musculoskeletal injury rates [16–18]. All these factors should be carefully considered when planning and implementing optimal physical training programs for soldiers.

To meet the occupational requirements, it is important to determine the best training programs and periodization models for a soldier. Decreased overall physical activity and fitness of recruits creates more demands for their initial training [19]. The increase in daily activity in garrisons can result in a sudden increase in recruits' physical activity, which increases the risk of overtraining or injury [16,18,20,21]. Therefore, it is crucial to have a well-planned and periodized physical training program taking into account the initial physical performance level. In the past, most physical programs have concentrated on improving aerobic endurance of recruits using traditional periodization [2]. A more suitable approach may be the use of an undulating or a block periodization model with elements of aerobic and anaerobic conditioning and strength training [22–27]. In addition, due to strict timetables, physical training should be incorporated into the occupational training of a soldier, and the majority of training should be performed wearing a uniform and in field conditions [28]. This would help soldiers to train more occupational skills and to better adapt to different terrains: possibly decreasing injuries during training. Both the decline in physical fitness and the higher demands in occupational requirements of the recruits have led to a situation, where systematically designed, tailored, and supervised physical training that meets the occupational task requirements needs to be performed during the basic training [29]. While designing a training plan for soldiers, it is essential to evaluate the components emphasizing the occupational task requirements. The result of physical training programs relies on training frequency, intensity (velocity and load), and volume (repetitions and duration), which form the foundation of training [2]. To enhance and optimize training adaptations and to reduce overtraining and training-related injuries in training, it is crucial to plan and organize the training individually [30] (p. 205). Nevertheless, it is critical that these emphasized training factors are well related to individual needs, and the initial fitness level of the trainee, and the training plan is well periodized. Additionally, variation in training stimulus is one of the most crucial components when considering the development of explosive or maximal strength and maximal aerobic capacity [30] (pp. 260–263 and 299–300). Daily military training can be too monotonous and may not enhance a soldier's physical performance by the best possible way. Professional soldiers should have access to training programs, which first helps them to reach and then to maintain the required level of physical performance [31].

In the past, there have been studies regarding specific occupational task tests for soldiers [1,32,33]. These studies have shown that a soldier needs both aerobic and anaerobic endurance and muscle strength to fulfill occupational requirements. Mala et al. [32] observed that strength and power were strongly related to high-intensity military tasks with and without heavy load carriage. Pihlainen et al. [33] showed that the maximal countermovement jump (CMJ), 3000 m running time, skeletal muscle mass, and repeated push-ups explained about 60% of military simulation test time. In addition, in a study by Sporis et al. [26] anaerobic endurance and strength were found to be important factors in the soldiers' performance. According to the current literature, it seems that there is no "gold standard" to measure soldiers' occupational physical performance. As a consequence, the most effective way to train to improve these occupational requirements has not been studied sufficiently. Thus, the purpose of this study was to determine which physical abilities are important for soldiers during a repeated simulated military task course and which type of training (task specific, strength, or traditional military fitness training) would be useful and contribute to gains in these abilities during a specialized military training period.

2. Materials and Methods

2.1. Subjects

A training group of forty-two (n = 42) male soldiers (age ranging from 18 to 22 years) participated in the study and performed all the measurements during the 12-week study period. Their mean (±SD) age was 20 (±1) years, height 180 (±6) cm, body mass 72.9 (±9.3) kg, and body mass index 22.6 (±2.3) kg·m^{-2} (Table 1). The subjects were all from the same infantry company, and they were divided into three training groups by their platoon as follows: soldier task specific training group (TSG), strength training group (STG), and control group (CON). The present study was conducted according to the provisions of the Declaration of Helsinki and the ethical statement of the Ethical Committee, the University of Jyväskylä. The study was approved by the Finnish Defence Forces. All the recruits were informed of the experimental design, and the benefits and possible risks that could be associated with the study prior to signing an informed consent to voluntary participate in the study.

Table 1. Mean (±SD) age, height, body mass, and body mass index (BMI) in the study groups.

Variable	TSG (n = 17)	STG (n = 15)	CON (n = 10)
Age (years.)	20 (±1)	20 (±1)	20 (±1)
Height (cm)	180 (±7)	183 (±6)	177 (±4)
Body mass (kg)	73.2 (±9.8)	73.8 (±7.8)	71.1 (±11.0)
BMI (kg·m^{-2})	22.7 (±2.2)	22.1 (±1.7)	22.7 (±3.7)

TSG, task specific group; STG, strength training group; CON, control group; BMI, body mass index.

2.2. Procedures

The study was implemented during the latter part of the Finnish conscript service, after the eight-week basic training period (Figure 1). Physical performance tests and simulated military task performance were repeated three times during the training study, in the ninth week (PRE), sixteenth week (MID), and twenty-second week (POST) of their conscript service. The testing began in the morning with body composition measurements. After breakfast, the subjects performed muscular power, strength, and strength endurance tests. Finally, after lunch they performed the simulated military task performance test. Each training group completed their tests during the same day.

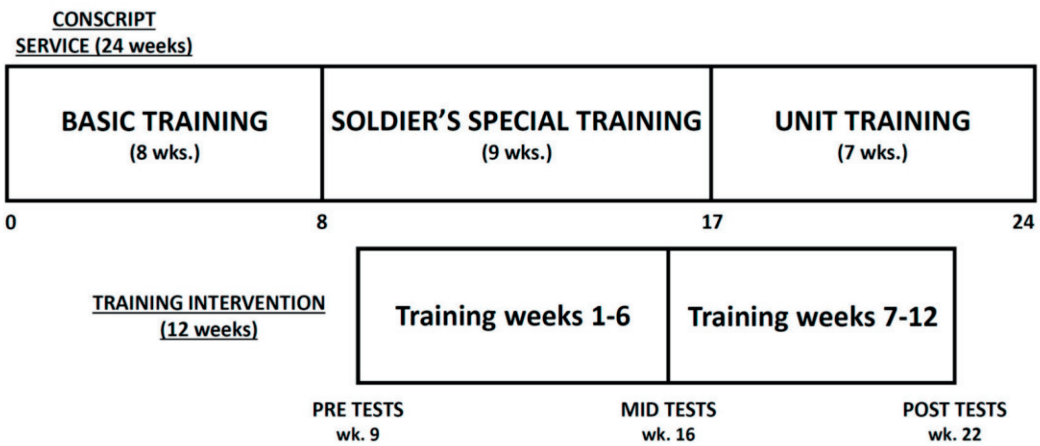

Figure 1. Timeline of the study.

2.2.1. Neuromuscular Performance

Maximal isometric bilateral force of the extensor muscles of the lower (MVClower) and upper (MVCupper) extremities was measured in a sitting position. The measurements were conducted using an electromechanical dynamometer [34] manufactured by the University of Jyväskylä (Jyväskylä, Finland). In the upper extremity test, the pushing bar was adjusted to the height of the shoulders and the distance of the seat was set to maintain an elbow angle of 90°. In the lower extremity test, the distance of the seat was set to maintain knee and hip angles of 107° and 110°, respectively. A countermovement jump (CMJ) was performed on a contact mat (Newtest, Oulu, Finland). Flight time between contacts was used to calculate the jumping height for each jump [35]. A six-second cycle ergometer test (Wattbike Ltd., Nottingham, UK) was used to measure maximal power of the lower extremities. The six-second test has a seated stationary start with a dominant leg initiating the first down-stroke. The test started following a five-second countdown followed by verbal command. The completion of the test was also indicated with another verbal command [36].

2.2.2. Simulated Military Task Performance

The simulated military task performance consisted of typical army soldier tasks and maneuvers, such as sprints, crawling, carrying objects, and casualty evacuation. It was performed inside on an artificial turf with soldiers wearing typical combat gear, including the helmet (total extra weight of 22-kg). From the starting (lying) supine position, the soldiers performed a 10 m sprint, followed by a 10 m low crawl. After the low crawl, the subjects lifted, carried, and lowered two 16-kg kettlebells (CompactFit Ltd., Helsinki, Finland) twice for a distance of 10 m taking a supine position when lowering the kettlebells. This was followed by a 75-kg sandbag drag (Rogue Sandbag, Rogue Fitness Europe Ltd., Pori, Finland) for 10 m, followed by a sprint of 10 m. The total length of the track was 60 m (Figure 2).

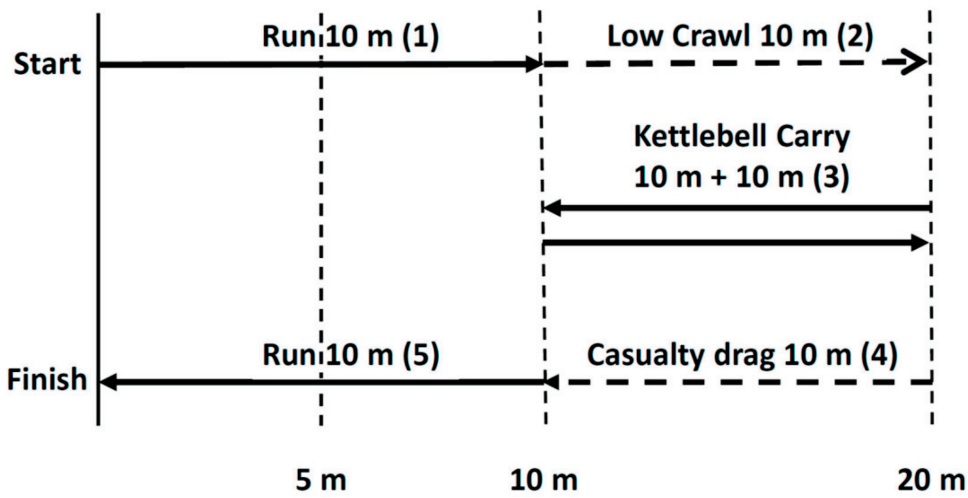

Figure 2. Outline of the simulated military task performance course. Different tasks are numbered in the order of performance (1–5).

The track was performed three times with a 60 s rest between the trials. Before the simulated military task performance, the subjects were individually familiarized with the track by a supervisor who also gave verbal instructions and encouraged the subjects during the test. The performance time was recorded by a stopwatch and video recorded for a later verification. The split times for different tasks were obtained offline from the video. Heart rate was recorded throughout the test by the Firstbeat team system (Firstbeat Technologies, Jyväskylä, Finland) and peak heart rate was determined from the data. Blood lactate was analyzed (Biosen c-line Sport, EKF Diagnostic, Madgeburg, Germany) from the fingertip (20 µL) five times (before, after each trial and 10 min after the final trial). The sensitivity for lactate analysis was 0.5 mmol/L and interassay coefficient of variation was 6.2%. Before and immediately after the simulated military task performance, the participants shot 10 rounds (Eko-Aims Ltd., Ylämylly, Finland) from a prone position with a similar army assault rifle replica (RK95, Finland) that they handle daily in their military training. The sum of ten shots was recorded for further analysis.

2.3. Training Protocols

Training programs were designed to be performed as a part of the recruits' normal weekly physical training. During the 12-week training period, the total number of instructed physical training sessions performed by the recruits was 12 during the first six weeks and six sessions during the latter six weeks of the study. They also conducted their normal military training every day, which consisted of road marches, shooting exercises and other task specific exercises. Variation of the instructed physical training program was due to military field training (MFT), which was a part of their training program. During those weeks, the conscripts were not able to perform any extra physical training. All the groups participated in the instructed physical training, but the content of training varied between the groups. All of them performed 10 min active warm-up, which included body weight movements, active stretching, and running, before starting the actual exercise. The total length of one session was 60 min in all groups. The average daily RPE (Borg's scale 6–20) varied during the training days as follows; TSG 10.7–13.4, STG 10.2–14.7, and CON 10.2–14.4 without significant differences between the groups. Training sessions of the TSG group included basic infantry-based exercise with full combat gear (27 kg), such as sprints, crawling, and casualty drag. Exercises were performed with anaerobic emphasis for 30–60 s. The STG group trained with the non-linear strength training program. The full-body program included squats, hamstring curls, pull and push exercises for the upper body, and different core exercises. The program began with low-load and high-repetition (40–60% of one-repetition maximum (1RM), 12–15 reps), continued to moderate-load and volume (70–85% of 1RM, 6–12 reps) culminating in high-load and low-volume training (85–100% of 1RM, 1–4 reps). CON performed normal Finnish Army military physical training only. A typical training session included circuit training with body weight, running with a constant pace, or playing different ball games. The training protocols for each group are presented in more detail in the previously published paper [37].

2.4. Statistical Analysis

The data for the present study was analyzed using commercial statistical software (IBM SPSS 24.0 Chicago, IL, USA). All data were checked for normality when calculating descriptive values for all variables. Conventional statistics were used to calculate means, 95% confidence intervals, and standard deviations (±SD). Effects sizes were calculated according to Cohen [38] (0.2 = small; 0.5 = medium; and 0.8 = large effect). Probability adjusted t tests were used for pairwise comparisons when appropriate. A general linear model, with repeated measures ANOVA with group as a fixed factor, was used to analyze the time × group interaction and the differences between the different measuring points. Associations between physical performance and military task test were performed using a Pearson correlation coefficient. Statistical significance for this investigation was set at $p \leq 0.05$ (two-tailed).

3. Results

3.1. Neuromuscular Tests

Maximal isometric strength produced during the bilateral leg press increased significantly between the PRE and MID and PRE and POST measurements in TSG, but not in STG and CON. Maximal isometric strength during the bilateral bench press increased significantly in STG between the PRE and MID and PRE and POST measurements. In TSG, a significant increase occurred between the MID and POST measurements. No significant differences between the groups were observed in these maximal isometric forces.

In all groups significant increases occurred in 6 s maximal anaerobic power in the cycle ergometer test between PRE and POST (Table 2). TSG and STG also showed significant increases in power between the PRE and MID measurements, but not CON. In CMJ, a significant increase occurred in jump height between PRE and POST in TSG and between MID and POST in TSG. No significant differences were observed between the groups in the changes in CMJ.

Table 2. Mean ± SD, 95% confidence interval (CI), and effect size values in the maximal neuromuscular tests in the PRE, MID, and POST measurement points.

		PRE		MID		POST		|Effect Size|		
	Group	**Mean (±SD)**	**95% CI**	**Mean (±SD)**	**95% CI**	**Mean (±SD)**	**95% CI**	**1 vs. 2**	**2 vs. 3**	**1 vs. 3**
CMJ (cm)	TSG	29 ± 6	26; 32	29 ± 5	26; 31	31 ± 4 *,#	28; 33	0.00	0.43	0.38
	STG	33 ± 6	29; 36	33 ± 5	30; 36	35 ± 4	32; 37	0.00	0.43	0.38
	CON	32 ± 6	28; 36	31 ± 7	26; 35	31 ± 6	27; 35	0.15	0.00	0.16
POWER (w)	TSG	1036 ± 140	961; 1110	1078 ± 138 *	1004; 1151	1094 ± 125 **	1027; 1160	0.30	0.12	0.43
	STG	1097 ± 98	1043; 1152	1140 ± 92 *	1090; 1192	1141 ± 103 *	1084; 1198	0.44	0.01	0.43
	CON	974 ± 122	886; 1061	1007 ± 144	904; 1110	1027 ± 147 *	922; 1132	0.24	0.13	0.38
UPPER BODY STRENGTH (kg)	TSG	78 ± 14	71; 86	77 ± 13	70; 84	80 ± 12 ##	74; 87	0.07	0.23	0.15
	STG	79 ± 14	72; 87	83 ± 14 *	75; 90	84 ± 14 **	77; 92	0.28	0.06	0.35
	CON	75 ± 14	65; 85	75 ± 15	65; 86	77 ± 16	65; 88	0.00	0.17	0.18
LOWER BODY STRENGTH (kg)	TSG	236 ± 40	214; 257	252 ± 39 *	231; 273	255 ± 50 **	239; 284	0.40	0.07	0.41
	STG	229 ± 49	202; 256	242 ± 39	221; 264	244 ± 39	223; 266	0.29	0.05	0.33
	CON	224 ± 50	189; 260	234 ± 57	193; 275	236 ± 56	195; 276	0.18	0.03	0.22

CMJ, countermovement jump; POWER, maximal 6 s power cycling; UPPER BODY STRENGTH, maximal isometric bilateral extension; LOWER BODY STRENGTH, maximal bilateral extension; TSG, task specific group; STG, strength training group; CON, control group. * = compared to PRE values * = $p < 0.05$, ** = $p < 0.01$; # = compared to MID values, # = $p < 0.05$, ## $p < 0.01$.

3.2. Simulated Military Task Performance

3.2.1. Total Time

The total time of the first trial in the simulated military task performance improved in TSG and STG between the PRE and MID measurements by 11.1% (ES = 0.64) and 9.4% (ES = 0.91) and between the PRE and POST measurements by 11.4% (ES = 0.74) and 8.8% (ES = 0.72), respectively. No significant changes were observed in CON between the measurements in the first trial. In the second trial, the total time improved significantly in TSG and STG between the PRE and MID measurements by 14.6% and 13.1%. All groups showed significant improvements between the PRE and POST measurements (TSG: 17.0%, STG: 14.1%, and CON: 12.0%, ES = 1.35, 1.12, and 0.76, respectively). There was also a significant improvement in CON between the MID and POST measurements (6.3%, ES = 0.36). A similar trend was also observed in the third trial. Significant improvement was found between the PRE and MID measurements in TSG (14.6%, ES = 0.78) and STG (15.7%, ES = 1.05), but not in CON (2.1%, ES = 0.08). Between the PRE and POST measurements, a significant improvement occurred in all groups (TSG 19.2%, ES = 1.01, STG 18.2%, ES = 1.23, and CON 12.1%, ES = 0.77). TSG and CON showed a significant improvement between the MID and POST measurements (TSG 5.3%, ES = 0.32, and CON 9.6%, ES = 0.52; Figure 3).

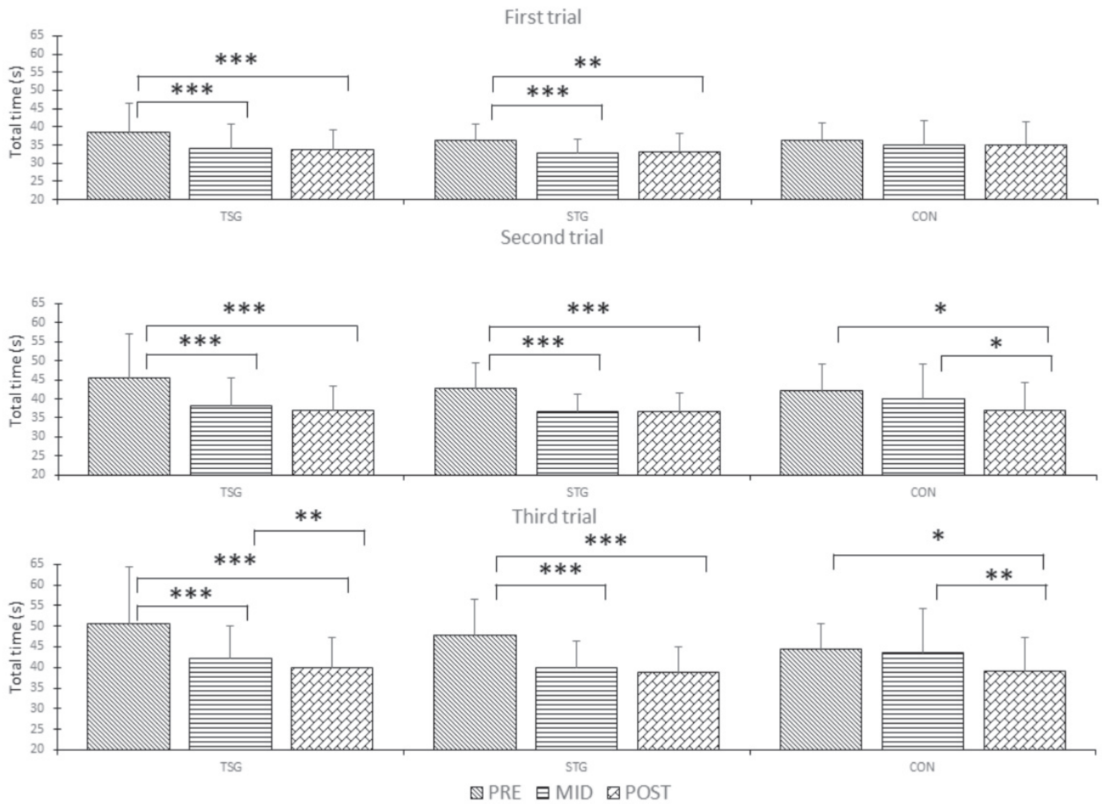

Figure 3. Total time (s) in the simulated military task course (first, second, and third trial). STG = strength training group; TSG = soldier task specific group; CON = control group; * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

3.2.2. Five Meters Run from the Start

No significant changes were found in running time over the first 5 m during the first trial. (Table 3) During the second trial, TSG and CON significantly improved between the PRE and POST measurements. (Table 4) In the third trial, TSG and STG significantly improved between PRE and MID. CON improved significantly only between the PRE and POST measurements (Table 5).

Table 3. Simulated military task performance times for different tasks (first 5 m run, crawl, kettlebell carry (KB), casualty drag, and final 10 m run) from the first trial in the PRE, MID, and POST measurements points.

First Trial		PRE		MID		POST		|Effect Size|		
Performance Measure	**Group**	**Mean (±SD)**	**95% CI**	**Mean (±SD)**	**95% CI**	**Mean (±SD)**	**95% CI**	**1 vs. 2**	**2 vs. 3**	**1 vs. 3**
5 m run (s)	TSG	2.5 ± 0.3	2.4; 2.7	2.5 ± 0.4	2.3; 2.7	2.4 ± 0.3	2.3; 2.6	0.23	0.13	0.41
	STG	2.5 ± 0.2	2.4; 2.6	2.4 ± 0.2	2.3; 2.5	2.4 ± 0.2	2.3; 2.5	0.32	0.10	0.39
	CON	2.6 ± 0.4	2.3; 2.9	2.5 ± 0.3	2.3; 2.8	2.5 ± 0.3	2.3; 2.7	0.22	0.03	0.26
Crawl (s)	TSG	8.0 ± 2.0	7.0; 9.1	6.7 ± 1.8 ***	5.8; 7.7	6.4 ± 1.3 ***	5.7; 7.1	0.69	0.22	0.96
	STG	7.5 ± 1.4	6.8; 8.3	6.5 ± 1.2 **	5.8; 7.2	6.4 ± 1.7 **	5.4; 7.4	0.81	0.05	0.74
	CON	7.3 ± 1.0	6.5; 8.0	6.6 ± 1.8	5.4; 7.9	6.6 ± 1.8	5.3; 7.8	0.47	0.05	0.53
KB carry (s)	TSG	12.0 ± 1.9	11.0; 12.9	11.0 ± 1.7 ***	10.1; 11.8	11.1 ± 1.8 *	10.2; 12.0	0.58	0.08	0.50
	STG	11.5 ± 1.2	10.8; 12.1	10.8 ± 1.1 *	10.2; 11.4	10.9 ± 1.4	10.1; 11.7	0.61	0.07	0.47
	CON	11.5 ± 1.3	10.6; 12.4	11.2 ± 1.4	10.2; 12.2	11.2 ± 1.3	10.2; 12.1	0.22	0.04	0.26
Drag (s)	TSG	11.7 ± 3.7	9.8; 13.6	9.8 ± 2.4 ***	8.6; 11.1	9.7 ± 2.3 ***	8.5; 10.9	0.61	0.04	0.65
	STG	10.6 ± 2.4	9.3; 12.0	9.2 ± 1.6 **	8.4; 10.1	9.6 ± 1.9 *	8.5; 10.7	0.72	0.11	0.49
	CON	10.7 ± 2.0	9.3; 12.1	10.6 ± 3.2	8.3; 12.9	10.5 ± 2.9	8.4; 12.5	0.04	0.05	0.11
10 m run (s)	TSG	3.1 ± 0.4	2.9; 3.4	3.0 ± 0.4 *	2.8; 3.1	2.9 ± 0.3 *	2.8; 3.1	0.54	0.03	0.64
	STG	3.1 ± 0.4	2.9; 3.4	2.9 ± 0.3 ***	2.7; 3.0	2.9 ± 0.3 *	2.7; 3.0	0.74	0.18	0.72
	CON	3.1 ± 0.5	2.7; 3.4	3.0 ± 0.5	2.6; 3.4	3.0 ± 0.6	2.6; 3.4	0.14	0.04	0.10

TSG = soldier task specific group; STG = strength training group; CON = control group; * = compared to PRE values * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

Table 4. Simulated military task performance times for different tasks (first 5 m run, crawl, kettlebell carry (KB), casualty drag, and final 10 m run) from the second trial in the PRE, MID, and POST measurement points.

Second Trial		PRE		MID		POST		|Effect Size|		
Performance Measure	**Group**	**Mean (±SD)**	**95% CI**	**Mean (±SD)**	**95% CI**	**Mean (±SD)**	**95% CI**	**1 vs. 2**	**2 vs. 3**	**1 vs. 3**
5 m run (s)	TSG	2.6 ± 0.4	2.4; 2.8	2.5 ± 0.3	2.3; 2.6	2.5 ± 0.3 *	2.3; 2.6	0.24	0.21	0.21
	STG	2.6 ± 0.2	2.4; 2.7	2.5 ± 0.2	2.4; 2.7	2.4 ± 0.2	2.3; 2.6	0.10	0.43	0.55
	CON	2.8 ± 0.2	2.7; 3.0	2.6 ± 0.5	2.3; 3.0	2.6 ± 0.4 *	2.4; 2.9	0.60	0.05	0.68
Crawl (s)	TSG	9.7 ± 2.9	8.2; 11.2	7.7 ± 2.0 ***	6.7; 8.7	7.1 ± 1.5 ***,##	6.3; 7.9	0.81	0.37	1.12
	STG	8.9 ± 1.9	7.8; 9.9	7.7 ± 1.5 *	6.9; 8.6	7.5 ± 1.9 ***	6.4; 8.5	0.69	0.16	0.77
	CON	8.4 ± 1.7	7.2; 9.7	7.8 ± 2.2	6.2; 9.4	7.1 ± 1.8 **,#	5.9; 8.4	0.33	0.35	0.78
KB carry (s)	TSG	14.1 ± 3.4	12,4; 15.8	12.3 ± 1.9 **	11.4; 13.3	11.9 ± 1.8 ***,#	11.0; 12.8	0.68	0.23	0.85
	STG	13.0 ± 1.5	12.2; 13.8	11.9 ± 1.1 ***	11.2; 12.5	11.6 ± 1.2 ***	10.9; 12.3	0.90	0.22	1.06
	CON	13.0 ± 2.0	11.6; 14.4	12.7 ± 2.1	11.2; 14.2	11.7 ± 1.6 **,###	10.6; 12.8	0.33	0.58	0.79

Table 4. *Cont.*

Second Trial		PRE		MID		POST		|Effect Size|		
Performance Measure	Group	Mean (±SD)	95% CI	Mean (±SD)	95% CI	Mean (±SD)	95% CI	1 vs. 2	2 vs. 3	1 vs. 3
Drag (s)	TSG	14.2 ± 5.2	11.5; 16.9	11.5 ± 3.0 ***	9.9; 13.0	11.2 ± 2.8 ***	9.7; 12.6	0.66	0.10	0.74
	STG	13.6 ± 4.2	11.3; 15.9	10.9 ± 1.9 **	9.9; 12.0	10.8 ± 2.6 ***	9.3; 12.3	0.85	0.06	0.83
	CON	13.4 ± 2.9	11.3; 15.4	12.3 ± 3.8	9.7; 15.0	11.3 ± 3.5	8.8; 13.8	0.32	0.30	0.67
10 m run (s)	TSG	3.5 ± 0.6	3.2; 3.8	3.2 ± 0.4 *	3.0; 3.4	3.3 ± 0.4 *	3.1; 3.4	0.59	0.06	0.54
	STG	3.6 ± 0.4	3.3; 3.8	3.1 ± 0.3 ***	2.9; 3.3	3.1 ± 0.3 ***	3.0; 3.3	1.12	0.25	1.28
	CON	3.5 ± 4.0	3.2; 3.8	3.4 ± 0.7	2.8; 3.9	3.2 ± 0.5*	2.8; 3.5	0.30	0.26	0.78

TSG = soldier task specific group; STG = strength training group; CON = control group; * = compared to PRE values * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$; # = compared to MID values # = $p < 0.05$, ## = $p < 0.01$, ### $p < 0.001$.

Table 5. Simulated military task performance times for different tasks (first 5 m run, crawl, kettlebell carry (KB), casualty drag, and final 10 m run) from the third trial in the PRE, MID, and POST measurement points.

Third Trial		PRE		MID		POST		|Effect Size|		
Performance Measure	Group	Mean (±SD)	95% CI	Mean (±SD)	95% CI	Mean (±SD)	95% CI	1 vs. 2	2 vs. 3	1 vs. 3
5 m run (s)	TSG	2.9 ± 0.6	2.6; 3.2	2.6 ± 0.3 ***	2.4; 2.8	2.6 ± 0.3 ***	2.4; 2.7	0.70	0.16	0.81
	STG	2.8 ± 0.3	2.6; 2.9	2.6 ± 0.2 **	2.5; 2.7	2.6 ± 0.3 *	2.4; 2.7	0.81	0.04	0.78
	CON	2.8 ± 0.5	2.5; 3.2	2.9 ± 0.7	2.5; 3.4	2.7 ± 0.5 ##	2.4; 3.0	0.22	0.43	0.25
Crawl (s)	TSG	11.2 ± 3.6	9.4; 13.1	8.9 ± 2.3 ***	7.7; 10.1	7.9 ± 1.8 ***,##	7.0; 8.9	0.80	0.47	1.19
	STG	10.6 ± 2.6	9.2; 12.1	8.5 ± 2.0 ***	7.4; 9.6	8.0 ± 1.6 ***	7.1; 8.8	0.93	0.30	1.26
	CON	9.0 ± 1.5	7.9; 10.1	9.2 ± 3.3	6.9; 11.6	7.4 ± 1.9 *,#	6.0; 8.8	0.08	0.71	0.99
KB carry (s)	TSG	15.4 ± 3.8	13.4; 17.3	13.4 ± 2.2 ***	12.2; 14.5	12.9 ± 2.7 ***	11.5; 14.3	0.67	0.20	0.79
	STG	14.0 ± 1.9	13.0; 15:0	12.6 ± 1.5 **	11.8; 13.4	11.9 ± 1.4 ***,##	11.1; 12.7	0.86	0.46	1.28
	CON	13.6 ± 1.7	12.4; 14.8	13.5 ± 2.4	11.8; 15.2	11.8 ± 1.9 **,###	10.4; 13.1	0.08	0.84	1.09
Drag (s)	TSG	15.9 ± 5.8	12.9; 18.9	13.0 ± 3.1 **	11.4; 14.6	11.9 ± 2.6 ***,#	10.6; 13.2	0.64	0.40	0.92
	STG	15.6 ± 5.6	12.5; 18.7	12.1 ± 3.4 ***	10.2; 14.0	11.9 ± 4.1 ***	9.6; 14.2	0.77	0.07	0.78
	CON	13.8 ± 2.9	11.7; 15.9	13.2 ± 3.8	10.4; 15.9	12.4 ± 3.3	10.0; 14.8	0.20	0.22	0.47
10 m run (s)	TSG	3.8 ± 0.6	3.5; 4.1	3.4 ± 0.3 **	3.2; 3.6	3.4 ± 0.4 *	3.2; 3.6	0.84	0.06	0.72
	STG	3.5 ± 0.3	3.3; 3.7	3.3 ± 0.5	3.0; 3.6	3.2 ± 0.4 *	3.0; 3.4	0.40	0.25	0.83
	CON	3.6 ± 0.5	3.2; 4.0	3.7 ± 0.7	3.1; 4.2	3.5 ± 0.8	2.9; 4.0	0.12	0.26	0.18

TSG = soldier task specific group; STG = strength training group; CON = control group; * = compared to PRE values * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$; # = compared to MID values # = $p < 0.05$, ## = $p < 0.01$, ### $p < 0.001$.

3.2.3. Ten Meters Crawl

TSG and STG significantly improved their time in the first trial between the PRE and MID and PRE and POST measurements. (Table 3) In the second trial, TSG and STG improved crawling time between PRE and MID and between PRE and POST. CON improved crawling time between the PRE and POST measurements. TSG and CON also improved their time between MID and POST (Table 4). In the 3rd run, TSG and STG improved crawling time between PRE and MID and between PRE and POST. CON improved time between PRE and POST. Between MID and POST, there was a significant improvement in TSG and CON (Table 5).

3.2.4. Ten + Ten Meters Kettlebell Carry

TSG and STG improved carry time in the first trial between the PRE and MID measurements. TSG also improved its time between the PRE and POST measurements (Table 3). In the second trial, TSG and STG improved their carry time between PRE and MID and between PRE and POST. CON also improved its time between the PRE and POST measurements. STG and CON improved their time between the MID and POST measurements (Table 4). TSG and STG improved their carry time in the third trial between PRE and MID and PRE and POST. CON also improved its time between the PRE and POST measurements. STG and CON improved their time between the MID and POST measurements (Table 5).

3.2.5. Mannequin Drag

In 75 kg mannequin drag, there were improvements in the first trial in TSG and STG between the PRE and MID and PRE and POST measurements. (Table 3) Similar results were also observed between the PRE and MID measurements in TSG and STG in the second trial (Table 4) and in the third trial (Table 5), and between PRE and POST in the second trial (Table 4) and in the third trial (Table 5). No significant changes in the mannequin drag were found in CON.

3.2.6. Ten Meters Run

There were significant improvements during the first trail in TSG and STG between PRE and MID and PRE and POST (Table 3). Furthermore, during the second trial, there were significant improvements in TSG and STG between PRE and MID and PRE and POST. In addition, CON improved its time between PRE and POST (Table 4). In the third trial, TSG improved its time between PRE and MID and between PRE and POST. STG showed an improvement between PRE and POST (Table 5).

3.2.7. Blood Lactate and Heart Rate

Blood lactate and heart rate increased throughout the simulated military task performance in all measurement points. The highest values in blood lactate were measured in the POST measurement in all groups (ranging from 15.08 to 16.90 mmol/L). Mean heart rate varied between 172 and 182 bpm during the simulated military task performance.

3.2.8. Associations between Body Composition, Physical Tests, and Simulated Military Task Performance

Absolute individual changes in physical tests and times in the simulated military task performance correlated negatively and significantly in the PRE ($p < 0.05$; r = −0.366 to −0.659), MID (r = −0.352 to −0.789), and POST(r = −0.338 to −0.725) measurements. Furthermore, absolute individual changes in physical performance and individual changes in the simulated military task performance, correlated significantly between the PRE–MID measurements in isometric leg press force (second trial; r = −0.396, $p = 0.009$) and in maximal power (first trial; r = −0.348, $p = 0.026$). Similar correlations were found between the PRE–POST measurements in leg strength (second trial; r = −0.333, $p = 0.031$), maximal power (first trial; r = −0.429, p = 0.005), and CMJ (first trial; r = −0.451, p = 0.003). In the MID and POST measurements, no significant correlations between the changes in different tasks were found.

When looking at the relative change in time in the PRE–MID time points compared to absolute PRE times, there was significant negative correlations in STG (r = −0.669, p = 0.003) and TSG (r = −0.666, p = 0.007) in the second trial and in STG (r = −0.766, p = 0.000) in the third trial. In the CON group, respectively, no significant correlation was found (Figure 4).

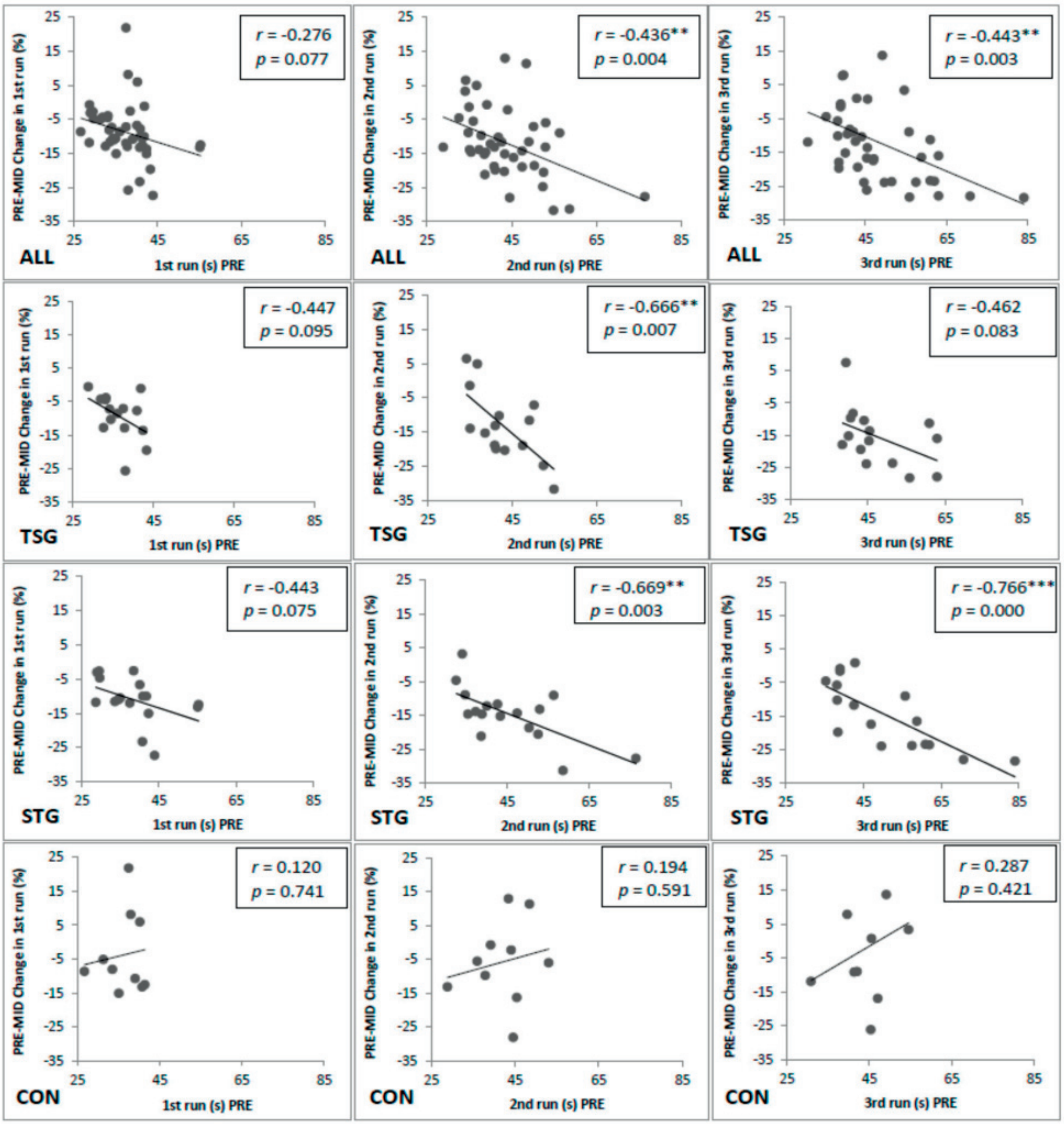

Figure 4. Correlations between absolute time in the 1st, 2nd, and 3rd run and the PRE–MID change (%) in time. ALL = all subjects; STG = strength training group; TSG = soldier task specific group; CON = control group; * = $p < 0.05$, ** = $p < 0.01$, *** = $p < 0.001$.

4. Discussion

The main finding of the present study showed that STG and TSG improved performance in the simulated military task course more than CON during the first six weeks of the study period (PRE–MID). During the second six weeks of the study (MID–POST), the subjects were able to maintain physical fitness and simulated military task course performance despite the high amount of military field training and the decreased number of physical training sessions.

It is necessary for soldiers to have an appropriate physical performance level, before military field training (MFT) or deployment. As seen previously, MFT may have unfavorable effects on soldier's physical performance and activity levels [16,20]. Hence, it is crucial to have an adequate recovery period after a long military training course or MFT to retrieve combat readiness [39]. Altogether, military training and deployments create a complicated environment for strength development due to the fact that endurance training is fully integrated into soldiers' daily training. It has been shown that high (>3 times/week) endurance training frequency, especially with high training volumes, may have a negative influence on strength and, specifically, explosive performance during their concurrent training [40–42]. Daily military training may also have a similar effect on the development of different physical characteristics.

When considering the physical performance tests, no significant changes were found between the training groups in all measurements. In the six-second cycling test, maximal power increased in all groups, but STG and TSG improved most between the PRE and MID measurements. In the maximal strength test, only significant improvements were observed in leg press in the TSG group and in bench press in the STG group. In CMJ, small significant improvements were noticed in the TSG and STG groups. Although no differences between groups were observed in the present study, greater improvements took place in the TSG and STG groups in the strength and power tests compared to the CON group. In addition, the improvements were similar in the TSG and STG groups. Thus, it seems that task-specific training is as effective as strength training to improve soldiers' military task specific performance. This finding is in line with a previous study done in the military environment [43], where no differences between the training groups were observed.

The total number of training sessions during the 12-week study period was 18. The first six weeks of the study was the actual training intervention period including 12 training sessions. Between the PRE and MID measurements, there was only one MFT, which lasted five days. During other weeks, the subjects had two to three training sessions as described earlier in the methods. The last six weeks of our study can be described as a maintenance period, because the subjects had four different MFTs during this period, lasting from four days to ten days. During this period the subjects had only six training sessions, zero to three times in a week. It has been shown earlier [44,45] that more than two sessions per week should be implemented to obtain improvements in strength and power performance in the military environment. In addition, the influence of military training [44,45] might have affected the outcome of the present study, especially, during the last six weeks.

Although no significant differences were found between TSG and STG in the simulated military task course, they both improved more than the CON group, especially, between the PRE and MID measurements. In addition, TSG seemed to have larger improvements in most parts of the course compared to STG, which may be explained by specific training with the same tasks as the actual simulated course in TSG [46]. It is also important to notice that the other groups had similar drills during the regular military training, but with lower volume and intensity. The results in our study support the findings by Harman et al. [43], where the training groups did high-intensity task-specific training as well. These improvements can also be explained by increased aerobic capacity, which could not be measured reliably in the present study. High-intensity interval training, performed by TSG, has been shown to lead to improvements in both aerobic and anaerobic performance [47]. Thus, when considering the results, it is possible that the task-specific training had more effect on improving both aerobic and anaerobic performance than strength-focused training. With regard to the improvement in the casualty drag, which involves moving a heavy load as fast as possible, both TSG and STG improved their performance significantly, but no significant changes were found in CON. This was probably due to the training of CON not including any maximal strength or high-power type of exercises. It has been shown in previous studies [29,32] that the ability to produce force and power is important in improving performance in these kinds of tasks. If the casualty drag would have been longer, most likely greater differences between TSG and STG compared to CON might have been observed. Furthermore, some indicators may demonstrate the specificity of the training, such as

STG improvements in isometric bench press between the PRE and MID measurements while TSG did not, and TSG improved maximal isometric leg press force between PRE and MID while STG did not. This was most likely due to the fact that the main focus in the TSG group was in lower body training, when STG performed also upper body exercises. This finding should be taken into account when planning training programs in the future. Upper body maximal strength has been shown to be important for soldiers' performance [48,49], and especially with field-based training, and must be taken into account when designing training programs. In addition, motivation has been shown to have a major impact to actual performance in these kinds of military task courses. Although all groups had high lactate values, CON seemed to have slightly lower concentrations compared to TSG and STG, but this might be because of their training, which did not include high intensity training.

With regard to the associations between different variables, there was a good correlation between the CMJ and six-second cycling power tests as compared to improved performance in the simulated military task course. This has also been found in previous studies when comparing power production and different task specific courses [32,50,51]. We also observed a significant correlation between time over the first five meters run and maximal upper body strength and push-up tests. Mala et al. [32] also found a similar association in their study. This can be explained by the type of task, which was performed starting in the prone position followed by standing up to run. This involves upper body extensors, which may be an important factor to perform the actual task [51]. The present study also showed that increased fat-free mass correlated significantly with the improvement in the simulated military task performance and with the increase in maximal isometric strength. These findings have been [32,51] shown to be important factors in evacuation tasks that involve high loads. When considering the PRE times and relative changes between the PRE and MID measurements, there was a significant correlation between the PRE time and magnitude of improvement in TSG and STG. Both task-specific and strength training programs were highly effective for the subjects who performed worse in the PRE measurements. Normal physical training did not have the same effect in CON.

In the present study, an endurance training group was planned to be included in the experimental design but because of a low number of subjects in this group, we had to drop it out of the study. The endurance group and a long duration endurance test would have provided more information on overall physical performance of the simulated military task performance. It should also be pointed out that the small number of the subjects were not fully familiar with all of our measurements prior to the study, because they had missed the familiarization session, but all the subjects were individually instructed in detail before the measurements. In addition, it should be remembered that all tasks in the simulated military test were the same as they performed throughout during their basic military training. In the future studies, it is important to include an endurance test in order to determine what physical abilities matter most in the simulated military task course.

The present study showed that both the task-specific and strength training programs were more effective than that of CON during the first six weeks in improving the performance in the repeated simulated military task course. It is important to have high-intensity training alongside with low-intensity military training to improve soldiers' task specific performance. The present study showed that task-specific training is as effective as that of strength training to improve the repeated simulated military task course time. This is an important finding, because this kind of training can be carried out without a high amount of equipment and in large groups compared to gym-based strength training. An optimal combination could include high-intensity simulated military task field training and strength focused gym training depending on the military training phase and environmental possibilities. In addition, an intensive six-week training period during the specialized military training can improve physical and military occupational performance in previously trained soldiers. In future studies it is important to compare different training programs over a longer follow-up period. In addition, it seems that it is also possible to maintain these levels of physical and military occupational performance during a six-week intensive military field-training period with only a few physical training sessions.

5. Conclusions

In summary, daily physical training recommendations should be dependent on the conventional characters of military training, which includes low-intensity and high-volume endurance training with an additional load of 25–65 kg. For this reason, progressively advancing combined strength, power, and endurance training including some proportion of high intensity interval training or microtraining seems to induce superior adaptations in a soldier's physical performance. In order to create more effective development in physical adaptations and performance, expanding attention should move towards more progressive and individualized physical training programs, which are split into phases that continuously improve performance. Therefore, an individualized approach to human performance optimization should be taken when trying to improve a soldier's physical fitness and to reach better operational readiness.

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