FLUCTUATIONS IN MUSCLE STRENGTH, SHOOTING ACCURACY AND SERUM HORMONE CONCENTRATIONS IN CONSCRIPTS DURING A 3-WEEK COMBAT TRAINING PERIOD

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ABSTRACT

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Conscripts and soldiers have to perform their duties in a multistressor environment. During prolonged periods of combat training, fluctuations in strength levels and hormone concentrations have been noted. However, there is limited information regarding the changes in shooting performance and whether changes in strength and hormonal concentrations are correlated with it. This study examined strength levels, shooting performance and hormonal fluctuations during a 3-week combat training period. Possible correlations between the variables were examined and investigated.

This study lasted for 37 days and involved 49 Finnish male conscripts as subjects. The subjects acted as their own controls during the first 11 days of the study. The control period was followed by a shooting camp which lasted for 5 days, and it was the first part of the prolonged combat training period. The following eight days consisted of combat camp1 (CC1) and immediately after that combat camp 2 (CC2) which also lasted 8 days. After the prolonged combat training period subjects had 5 days to recover. Measurements were taken on day 1, day 7, day 23, day 32, and day 37. The measurements included isometric leg press and isometric bench press for measuring strength levels of the lower and upper body. Shooting performance was measured from a standing and prone position. Serum cortisol, testosterone, and SHBG concentrations were analyzed from blood samples collected in a fasted state between 6.30am -7.30 am.

Significant fluctuations were observed in leg strength ($p \leq 0.05$) which decreased as loading was high, and after day 23 when loading was decreased, leg strength levels increased. The score from shooting in a standing position also decreased as the loading was high and as the loads began to decrease after day 23 the shooting standing score improved ($p \leq 0.001$). The shooting prone score did not show any significant changes throughout the study period. Serum cortisol concentrations increased significantly ($p \leq 0.001$) during the prolonged combat training period. Serum testosterone concentrations decreased ($p \leq 0.001$) during the prolonged combat training period. Significant positive correlations were observed in the changes in shooting standing scores and changes in strength levels for legs and upper body ($r=0.33$-$r=0.46$, $p \leq 0.05$- $p \leq 0.001$). After 5 days of recovery, all measured variables except cortisol returned to baseline levels.

The present findings showed that significant fluctuations in the strength levels, serum hormone concentrations and shooting scores took place during the prolonged combat training period. Changes in strength levels and changes in shooting performance were related as well as changes in serum cortisol concentrations and shooting standing score. Thus, a prolonged combat training period may have adverse effects in strength levels and the shooting ability in soldiers. Therefore, it is important that soldiers get an appropriate amount of rest while performing their duties.

Keywords: conscripts, strength, shooting, hormones, soldiers.

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LIST OF ABBREVIATIONS

CC1 - Combat camp 1

CC2 - Combat camp 2

GH - Growth hormone

MOS - Military occupational specialties

MVC - Maximal voluntary contractions

SHBG - Sex hormone binding globulin

VO_2 max - Maximal oxygen uptake

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1 INTRODUCTION

Soldiers are required to undergo combat training in a multistressor environment in order to be ready for similar situations in the case of war. During combat training, soldiers get a limited amount of sleep, food intake is not optimal and high stress levels are part of the training. (Nindl et al. 2007.) How this kind of an environment affects the soldier's neuromuscular system, hormonal responses and shooting accuracy is of interest to the military.

Previous research has demonstrated decrements in lower body strength as well as upper body strength after prolonged combat training period. The type of loading which the soldiers are subjected to seems to be the determining factor in what part of the body the fatigue is most evident. (Dziados et al. 1987; Kraemer et al. 1987; Knapik et al. 1990.) Previous literature also demonstrates the impact of prolonged combat training period on hormonal concentrations. Cortisol and sex hormone binding globulin (SHBG) concentrations have been shown to increase during prolonged combat training periods, whereas testosterone concentrations have been shown to decrease (Kyröläinen et al. 2008; Tanskanen et al. 2011) .

There is limited information regarding shooting performance and how it is affected by prolonged combat training periods. Available literature generally focuses on shooting accuracy after intense bouts of exercise and on biathlon where there are several studies that describe how shooting performance fluctuates as a result of different loading intensities (Hoffman et al. 1992; Vickers & Williams 2007). Since previous literature has shown that fatigue has a negative impact on shooting accuracy (Knapik et al. 1990; Tharion & Moore 1993), it is interesting to observe how both shooting from a standing position and from a prone position change during a prolonged combat training period.

This study monitored the fluctuations in upper and lower body strength levels during a prolonged combat training period. It also observed the changes in serum hormone concentrations as well as the changes in shooting accuracy during the study period. The study also aimed to distinguish if there were any correlations noted between the above mentioned variables and to see if five days of recovery at the end of the prolonged combat training period were enough to return all measured variables to the baseline levels.

2 NEUROMUSCULAR SYSTEM AND FATIGUE

The neuromuscular system comprises the nervous system and the muscles in the human body. The nervous system is basically divided into the central nervous system which comprises the brain and the spinal cord, and the peripheral nervous system which comprises the nerves and ganglia that are outside the brain and the spinal cord (Figure 1). (Taylor & Johnson 2008, 46; Purves et al. 2012, 11-12.) The basic function of the peripheral nervous system is to connect the central nervous system to the limbs and organs. It is the neuromuscular system that enables us to produce movement. (Taylor & Johnson 2008, 48-51; McArdle et al. 2010, 378.)

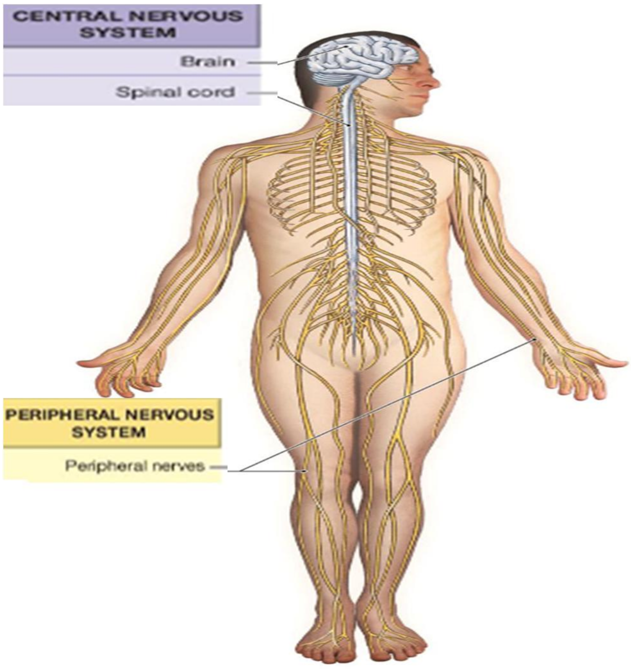

FIGURE 1. Central and peripheral nervous system (Martini, Timmons & Tallitsch 2012, 347.)

Muscles are the part of the neuromuscular system that produces movement. The ability to move is made possible by the interaction between the nerves and the muscle fibers. Alpha motor neurons are located at the roots of the brain and spinal nerves and are necessary for the control and functioning of the muscle. The alpha motor neuron and the muscle fibers which are innervated by it are called a motor unit. (Kjaer et al. 2003, 50; Purves et al. 2012, 11-12.)

Muscles have different amounts of motor units depending on the function and size of the muscle. Most skeletal muscles comprise a few hundred motor units. The force that a muscle produces is controlled by the central nervous system. Two key factors determine the amount of force that a muscle will produce: the number of motor neurons that are activated and, the rates at which they discharge action potentials. (Enoka 2002, 283-284; McArdle et al. 2010, 378.) Motor units are recruited in the order of small to large. The smaller, type one motor units are fatigue resistant compared to the larger, type two. This allows the bigger fatigable motor units to be recruited only when more force is needed. (Kjaer et al. 2003, 88.)

Fatigue can be defined as the decline in performance that results from exercise. Fatigue is generally considered to occur at either the muscle fiber level, known as peripheral fatigue, or at the central nervous system level, which is known as central fatigue. Either the peripheral or central factors can lead to fatigue in the neuromuscular system. If either peripheral or central systems are fatigued, a decline in the maximal force and rate of force development can be observed. (Enoka & Stuart 1992; Gandevia et al.1996.)

Central fatigue is characterized by a gradual decline in the ability of the central nervous system to activate a muscle maximally. The fatigue can result from a maximal performance or gradually over the duration of multiple repetitions. (Gandevia et al. 1996.) Central fatigue can lead to the inability of a person to perform a task even though the muscle tissue might still possess the ability to continue work (Taylor et al. 2000).

Peripheral fatigue can be described as the fatigue that occurs in the actual muscle, and it is characterized by a decline in the ability of the muscle to produce force (Nordlund et al. 2004). Peripheral fatigue can result from tiredness at any stage of voluntary activation of a muscle. Fatigue at the motor neuron level, neuromuscular junction or the depletion of energy stores are a few examples of the different reasons why peripheral fatigue might occur. (Kirkendall 1990.)

3 STRENGTH IN MILITARY

Muscle strength is characterized by the force generation capacity of a muscle or a group of muscles. Strength can be divided into isometric strength and dynamic strength. Isometric muscle action represents work where the length of the muscle does not change. Dynamic muscle action represents muscle work where the muscle either lengthens (eccentric) or shortens (concentric). (Kjaer et al. 2003, 55-57.) Maximal strength can be defined as the peak force developed during a maximal voluntary contraction (MVC) (MacDougall, Wenger & Green 1982, 21-25).

3.1 Importance of strength in military

Muscular strength is important for military personnel. In order for soldiers to be able to carry out their daily activities and duties they need to have good muscle strength. (Kraemer & Szivak 2012.) Even in the face of technological advancements in the military field, the modern soldier's tasks are nonetheless physically very demanding. Both lower body strength and upper body strength must be considered: marching long distances requires a soldier to have a strong lower body and for lifting and carrying heavy equipment a soldier must possess adequate upper body strength. (Welsh et al. 2008; Nindl et al. 2002.)

In order for soldiers to be able to carry heavy loads over long distances lower body strength is required (Table 1). Dziados et al. (1987) examined the effects of strength on a 16km road march and concluded that hamstring muscle strength was the only significant predictor of march performance. Knapik et al. (1990) examined how a 46kg load would affect a 20km road march. His group found statistically significant correlations between the strength of the lower body and the road march time. In yet another study, Mello et al. (1988) investigated the effects of carrying a 46.12kg load over two different distances of 8km and 12km. His group concluded that the strength of the hamstring muscles and quadriceps were important predictors of the ability to bear such loads over the two distances.

TABLE 1. Effects of lower body strength on marching performance

Marching Performance	Load Carried
· Over 16km road march, hamstring muscle strength only significant predictor of performance (Dziados et al. 1987)	· 18 kg
· Over 20 km road march, correlation between strength of lower body and road march time (Knapik et al. 1990)	· 46 kg
· Over 8km and 12km road march, hamstring and quadriceps important predictors (Mello et al. 1988)	· 46 kg

Upper body strength is important when considering the soldier's ability to carry objects and move from one location to another on foot (Table 2). Knapik et al. (1990) looked for any relationship between upper body strength and road march performance. A 46kg load was used and the distance marched was 20km. Abdominal strength was significantly related to the road march performance. Isometric upper body strength also showed a low but statistically significant correlation with the road march performance. Over a shorter distance of 3.2 km with similar loads of 44.7 kg, Kramer et al. (1987) demonstrated that the upper body strength more than the lower body strength was the critical factor in good performance.

TABLE 2. Effects of upper body strength on marching performance

Marching Performance	Load Carried
· Over 20 km road march, abdominal strength and isometric upper body strength correlated with march performance (Knapik et al. 1990)	· 46 kg
· Over 3.2 km road march, upper body strength more than lower body was a factor in good performance (Kraemer et al. 1987)	· 44.7 kg

Strength has an influence on other military related tasks. A soldier is expected to be able to construct defenses, rescue casualties, run fast from one cover to another and cross obstacles.

These are all tasks that tire the physiological system and strength is in an important role for the successful completion of these tasks. (Harman et al. 2008.)

Soldiers are regularly required to lift heavy loads and equipment (Blount et al. 2010). A study by Daniels et al. (1984) compared the aerobic power and the dynamic lift capacity with performance during a five day sustained combat scenario. They found that the individuals with the lowest lifting capacity were in the lower third of the group when judged by their performance score. The difference was not statistically significant but the combined ranking of the aerobic power and the lifting capacity had a clear correlation with field performance. (Daniels et al. 1984.)

The US Army Military Occupational Specialties (MOS) states that the infantryman must be able to raise and carry a person weighing 72.6 kg on their back, which is necessary when rescuing casualties. To lift and carry a casualty to a safer location requires significant amount of strength from a soldier. Speed is also important because the speed at which the rescue can be performed will often determine the chances of survival of the casualty as well as the survival chances of the person performing the rescue. A stronger and faster individual has the capability to perform a rescue faster. (Nindl et al. 2007.)

In a combat situation a soldier is required to be on the move. The moving can involve rushing from one cover to another during an engagement with the enemy. Blunt et al. (2010) demonstrated that the faster a soldier moves the shorter the time spent in the line of fire will be and this can improve his chances of survival. Five seconds is described as the maximum time that a soldier can be in the enemy line of sight. (Blount et al. 2010.) The world of exercise science has proved that strength is a critical component of speed and thus a stronger soldier should be able to move at faster speeds over short distances when rushing from one cover to another (Newton 2010).

Depending on the nature of the battlefield, soldiers will be required to go over or around obstacles. Physical fitness of soldiers is often measured using obstacle courses which include tasks such as running, jumping over hurdles, zigzagging, climbing a wall or platform, running up and downstairs and crawling (Bishop et al. 1999). The muscles of both the upper body and lower body are heavily tasked in the different parts of the obstacle course. Although the obstacle course might not represent the modern day battlefield in every aspect, there are many parts to it that are closely related to it. (Frykman et al. 2000.) Jumping, climbing and crawling are all movements that require high strength levels and in a battlefield situation they must be performed while carrying heavy loads (Harman et al. 2008).

Good physical fitness has been shown to reduce the risk of injury (Faigenbaum & Schram 2004; Sratton et al. 2004). Piirainen et al. (2008) demonstrated that conscripts who were at a greater fitness level had a lower rate of injury during the basic training period. Several studies in the field of exercise science have also demonstrated that strength training and higher strength levels coincide with lower injury levels, particularly in the lower extremities (Harman et al. 2008; Bergeron et al. 2011).

3.2 Nutrition and its effects on strength

Soldiers are constantly exposed to multiple stressors because of the nature of their tasks and duties. Physical and mental stresses during combat periods and prolonged physical work combined with inadequate rest and a calorie deficit have been shown to compromise physical performance. (Nindl et al. 2002.) US army rangers have reported calorie deficits that range between 2500 – 4500 kcal per day during operations (Figure 2). Such extreme calorie deficits can lead to significant changes in body composition and losses in lean body mass. The severity of the energy deficit and the duration that a soldier is forced to perform under such conditions can hamper the physical performance of the soldier. (Nindl et al. 2007.)

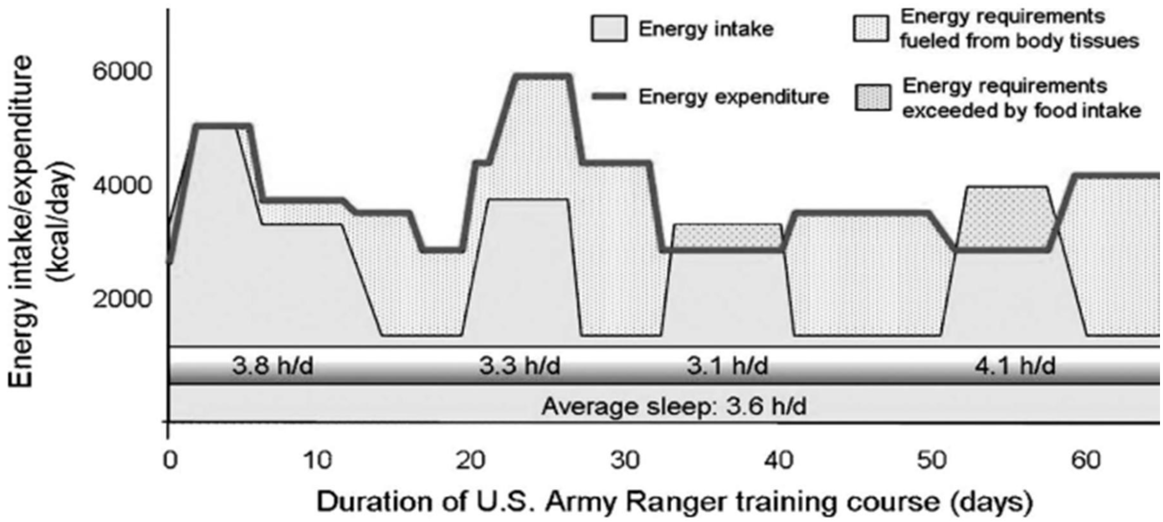

FIGURE 2. Energy intake and expenditure during US Army Ranger training course (Nindl et al. 2007)

Nindl et al. (1997) showed that muscular strength and power output were significantly affected by severe weight loss of 13-16% in the body mass over an 8 week period. However, there are studies that have indicated that over a shorter period of time and with lesser energy deficits physical performance decrements might be minimal. Fogelholm (1994) demonstrated that vertical jump power was not affected by a 5% weight reduction during a 3 week period. In a review by Friedl (1995) which focused on studies examining the effects of calorie deficit on soldiers' physical performance it was demonstrated that body mass losses of at least 5% and probably up to 10% were necessary before any decrements in performance would occur. Table 3 points out some of the effects that calorie deficit has on different strength aspects, which are further discussed in this chapter.

Knapik et al. (1990) found that upper body strength and anaerobic power were adversely affected by five days of combat training. No changes were noted in the lower body anaerobic mean power production. The discrepancies in the findings suggest that the specific activities that the soldiers are involved in during the training have an impact on which part of the body is more fatigued.

TABLE 3. Calorie deficit and how it affects different strength related components

	Calorie Deficit	Duration of Study
Body composition	· Significant changes, body mass decrease of 12.6% and fat free mass 6% (Nindl et al. 2007)	· 8 weeks
Lower body power	· Body mass losses of between 5-10% required for performance to be hampered (Friedl 1995) · 72 h operation, progressive decrement in lower-body ballistic performance (Nindl et al. 2002)	· (Review) · 3 days
Upper body power	· Adversely affected (Knapik et al. 1990)	· 5 days
Maximal power output	· 8 weeks of intensive military training led to 20% decline in max strength and power output (Nindl et al. 2007) · Severe weight loss of 13-16% significantly affected power output (Nindl et al. 1997)	· 8 weeks · 8 weeks
Obstacle course	· 3.1% loss in body mass, performance on obstacle course was adversely affected (Nindl et al. 2002)	· 3 days

A study by Nindl et al. (2002) attempted to evaluate the effects of a multistressor environment, which included calorie and sleep restriction and sustained physical exertion. The aim was to determine the impact that this environment would have on the soldiers' performance. In this study the energy deficit was estimated at -3000 kcal per day, the loss in body mass was 3.1% and the total amount of sleep was 3.6 hours during the 72 hour military operation. Their findings showed that the short term military operational stress adversely affected certain aspects of physical performance. A progressive decrement was seen in the lower body ballistic anaerobic performance but no changes were observed for upper body anaerobic performance and for the grenade throwing ability. This study also demonstrated that the performance on the obstacle course was adversely affected by the short term military operational stress. In this study, it was not possible to conclude if any one specific factor independently influenced the reductions in performance because the effects of physical exertion, sleep deprivation, energy restriction, and psychological stressors all may have had an impact. (Nindl et al. 2002.)

Nindl et al. (2007) showed that after 8 weeks of combat training consisting of high energy expenditure and restricted calorie intake there was a loss in body mass of 12.6 %, and a loss in fat free mass of 6%. This decline in body mass and fat free mass resulted in a 20% decline in the maximal lifting strength and power output. The vertical jump also showed a decrease of 16%. The decline in the maximum power output and not the maximal lifting strength were associated with losses in fat and fat free mass. (Nindl et al. 2007.) Previously mentioned studies indicate that negative effects can be expected during prolonged combat training periods, while training to enhance physical performance is important to minimize these decrements.

3.3 Sleep deprivation

Military as well as emergency personnel are often required to work under conditions of sleep deprivation. Studies have shown that sleep deprivation adversely affects performance on complex cognitive tasks as well as tasks which require substantial vigilance. (Nindl et al. 2002; Horne, Anderson & Wilkinson 1983.)

Spiegel et al. (1999) conducted a study where eleven men slept eight hours on the first three nights, four hours on the following three nights and then twelve hours on the final three nights. Stress hormone cortisol levels were elevated after the nights with 4 hours of sleep compared to the values recorded after the 8 and 12 hours of sleep. Cortisol is a catabolic hormone and, therefore its elevated levels may interfere with tissue repair and growth and thus lead to impairments in recovery. These impairments in recovery may over a prolonged period of time contribute to the decline of strength levels. (Spiegel et al. 1999.)

Spiegel et al. (1999) also demonstrated that under sleep restriction, young healthy males had glucose levels that were not normal. From the soldiers point of view, this is important because glucose and its storage form glycogen are important energy sources. For tasks requiring endurance, the storage of glucose in muscle and liver is critical. In a sleep deprived state glycogen storage slows down, thus preventing the individual from filling the glycogen reserves. The same study also indicated that the negative effects of sleep deprivation could be corrected by normal sleep patterns. (Spiegel et al. 1999.)

Daniels et al. (1984) demonstrated that 4 hours of sleep each night in soldiers enabled them to perform well the tasks that were required of them. Other studies have indicated that fitness does not provide any protection from the negative effects of sleep loss. However, there is a lack of literature on sleep deprivation and its effects on a soldier’s performance. (Daniels et al. 1984.) Further research is required to determine the minimal amount of sleep that a soldier should get during a prolonged training period in order for him to be able to maintain a high level of performance. Table 4 highlights some of the negative factors that can be observed as a result of sleep deprivation.

TABLE 4. Negative effects observed from the lack of sleep

	Lack of Sleep
Complex cognitive tasks	· Adversely affects performance (Nindl et al. 2002)
Cortisol	· Elevated levels (Spiegel et al. 1999)
Glycogen storage	· Slowed down (Daniels et al. 1984)

4 ENDOCRINE RESPONSES TO COMBAT TRAINING

4.1 Basic functions of the endocrine system

One of the main functions of the endocrine system is the maintenance of homeostasis in the human body (Greenstein & Wood 2011, 21; Borer 2013, 2). Hormones secreted by the endocrine system affect body growth and have an impact in enabling adaptations to mechanical challenges induced by exercise (Borer 2013, 2). For instance, during exercise blood flow is directed towards the working muscles and the digestive functions are put on hold (Bouchard et al. 2007, 84; Borer 2013, 2). In general, the alterations that occur in the endocrine system are automatic functions, and they are mostly beyond conscious detection or control (Borer 2013, 2).

Hormones are released by different body tissues and glands. The major endocrine glands include the hypothalamus, pituitary gland, thyroid gland, thymus gland, adrenal glands, kidneys, pancreas, ovaries, and testes. (Wilmore & Costill 2004, 160.) Hormones are categorized according to their chemical structure as steroid hormones, protein or peptide hormones, and amines (Guyton & Hall 2000, 836-837; Välimäki et al. 2000, 10; Bouchard et al. 2007, 84; Borer 2013, 6). Steroid hormones include the sex hormones which are testosterone in males and estrogen in females (Borer 2013, 11-12.)

Steroid hormones are normally released as soon as they are produced in response to a given stimulus (Kraemer & Rogol 2008, 10). The other hormones are different in that they are stored in intracellular vesicles, and when a certain stimulus is detected they are released (Borer 2013, 15). After being released hormones such as peptides, proteins, and amino acid-derived hormones are then transported in the circulation in their original form (Kraemer & Rogol 2008, 14).

Hormone release can be provoked by a number of different changes either in the internal or external environment. The goal of the release of hormones can be to correct an immediate imbalance or a longer duration imbalance or a sustained imbalance or adaptation. (Borer 2013, 15.) A few examples of external stimuli that can trigger an immediate hormonal response are physical or psychological stresses which provoke the activation and release of epinephrine and norepinephrine. (Guyton & Hall 2000, 839; Nussey & Whitehead 2001; Borer 2013, 15.) The endocrine gland that produces a hormone, releases it into the venous capillaries that surround the gland. The hormone is then transported back to the heart and lungs from where it enters the general systemic circulation. (Kraemer & Rogol 2008, 14.)

Once in the circulation, most hormones have short half-lives (Kraemer & Rogol 2008, 15). However, the amount of time it takes for the hormone to degrade can vary greatly. Some catecholamines have half-lives of only a few seconds while some thyroid hormones have half-lives of several days. In general, the length of the hormones half-live depends on the metabolism and clearance of it from the general circulation. (Guyton & Hall 2000, 840.) Most of the hormones are broken down within the liver and removed through the renal system (Nussey & Whitehead 2001).

4.2 Hormones and exercise

Exercise causes significant challenges to the homeostatic mechanisms (Wilmore & Costill 2004, 159). The mechanisms by which exercise is tolerated and the adaptions that occur as a result of exercise are closely related to hormonal regulation. The adaptations and changes seen are both acute and chronic. (Bouchard et al. 2007, 96; Kraemer & Rogol 2008, 5.)

Hormonal elevations are seen as a result of resistance exercise (Borer 2013, 186). The acute elevation in circulating blood hormone concentrations as a result of resistance exercise allows for an improved interaction with receptors located within the targeted tissue. The improved interaction with the receptor leads to an increase in muscle protein synthesis. The role of anabolic hormones such as testosterone in protein synthesis is important. (Kramer & Rogol 2008, 6.) Cortisol, on the other hand, exerts catabolic effects on muscle tissue (Greenstein & Wood 2011, 45; Borer 2013, 121). Studies have shown that intense physical exercise increases cortisol levels and this may inhibit protein synthesis which will consequently result in decreased muscle mass (Hayes et al. 2012). Testosterone circulating in the bloodstream is bound mostly to SHBG and this relationship makes the analysis of these two hormones relevant (Kraemer & Rogol 2008, 319). By binding to testosterone SHBG inhibits the function of testosterone because only free or unbound concentrations of hormones are biologically active. Therefore, the bioavailability of sex hormones is largely affected by the level of SHBG in the blood. (Anderson 1974.)

4.3 Hormonal responses to prolonged combat training

Soldiers are required to perform their duties in a multistressor environment and the responses that are triggered at the hormonal level are complex. This study focuses on the hormones testosterone, cortisol and SHBG and how their levels fluctuate during a prolonged combat training period. Table 5 highlights some of the hormonal responses that have been observed in previous studies. These studies are discussed further in this chapter.

TABLE 5. Hormonal responses to different periods of combat training

	Responses to combat training	Duration of study
Testosterone	· 86% drop in T levels (Friedl et al. 2000)	· 8 weeks
	· 24% drop in T, after a second 4 day period 30% drop in T (Nindl et al. 2005)	· 4+4 days
	· After a few days 27% decline in T (Kyröläinen et al. 2008)	· 20 days
Cortisol	· Increased when individuals were at minimal body fat (Friedl et al. 2000)	· 8 weeks
	· After first few days 32% increase in C levels (Kyröläinen et al. 2008)	· 20 days
	· Increases in cortisol noted (Santtila et al. 2009)	· 8 weeks
SHBG	· Elevated results, pre, after 4 weeks, after 7 weeks (Tanskanen et al. 2011)	· 8 weeks
	· Elevated results post 24h and 48h (McCaulley et al. 2009)	· 24h and 48h

Friedl et al. (2000) studied the effects of an 8 week US Army Ranger training period. During the 8 week period, the average soldier lost 15% in body mass, 7% in fat free mass and 65% of their fat mass. The average soldier demonstrated a 20% decline in their strength and an 86% drop in testosterone levels. (Friedl et al. 2000.) The decline in testosterone levels has been linked with overreaching and overtraining in athletes and, therefore, establishing whether such dramatic decline affects the soldiers performance is relevant (Nindl et al. 2005).

Nindl et al. (2005) conducted a study which looked at the effects of short term military operational stress on hormonal responses. This study consisted of two four day testing blocks during which subjects performed nearly continuous physical work and sleep was restricted to 1 hour sleep periods per day. The food intake was limited to one normal meal per day and an additional smaller meal per day. The meals accounted for a daily total calorie intake of 1600 kcal per day or an approximated deficit of 2500-2900 kcal per day. A 3% loss in body mass was observed after the four days and the total amount of sleep attained during the period averaged 6.2 hours. The decline of free testosterone observed in this study was 24% after the first four day training period and 30% after the second one. (Nindl et al. 2005.) These results are similar to other results in short term military training programs because Opstad (1992) found a 47% decline in testosterone levels after a five day military training course.

Tyyskä et al. (2010) studied the hormonal responses after a 15 day military field training period. Subjects in this study were army officers and their physical activity levels were described as low. The fifteen day military field training was considered a multistressor environment even though the physical strain encountered during this period was relatively small. The subjects did not endure extreme physical strain or energy deficit. Therefore, the hormonal responses were considered to be mainly due to disrupted sleep patterns and fitness status. The main finding from this study was that the testosterone to SHBG ratio decreased by 17% during the 15 day military field training. (Tyyskä et al. 2010.)

Concerning cortisol levels, a study by Friedl et al. (2000) demonstrated that cortisol levels started to increase significantly only at the very end of US Army Ranger course when fat reserves were almost completely depleted. This study consisted of four days of normal feeding which was followed by seven to ten days of energy restriction. During the period of energy restriction, soldiers performed eight to twelve kilometer patrols with loaded rucksacks weighing an average of 32.5kg in temperatures of 30 ºC. The soldiers got approximately 4.2 hours of sleep per night. Their cortisol levels remained stable for most of the ranger course, and only when individuals were at a minimal body fat level of 4% was a significant elevation in mean cortisol observed. This indicated that cortisol response may reflect the increased need to catabolize other body energy sources with the imminent depletion of fat stores. Another reason for the elevated cortisol levels may be a reduced clearance rate of cortisol, which has been observed in severely malnourished individuals. (Friedl et al. 2000.)

A study by Kyröläinen et al. (2008) looked at the effects of a prolonged, 20 day military field exercise on hormonal alterations. They concluded that during the first couple of days, there was a significant (32%) increase in cortisol and Growth hormone (GH) concentrations, and a decrease in testosterone and free testosterone levels of 27% and 26% respectively. The study was divided into three different phases: in the first phase, daily energy expenditure was approximately 7000 kcal per day; the second phase was considerably easier with daily energy expenditure of 3200 kcal and the third phase being slightly harder again with daily energy expenditure of about 4100 kcal per day. The first phase resulted in an increased cortisol and GH concentrations and decrease in testosterone and free testosterone levels (Figure 3). However, during the second phase which was significantly less fatiguing most of the hormonal concentrations recovered to the pre-exercise levels. During the third part of the training period, no significant changes were observed in the hormone concentrations. Perhaps the most important finding from this study was that during a prolonged military training period, it is important to have a lighter period in the middle of the training camp which allows the hormonal concentrations to recover to pre-exercise levels regardless of the continuous energy deficit. This tapering period seems to give the body a chance to adapt to the upcoming heavy exercise period (Kyröläinen et al. 2008.)

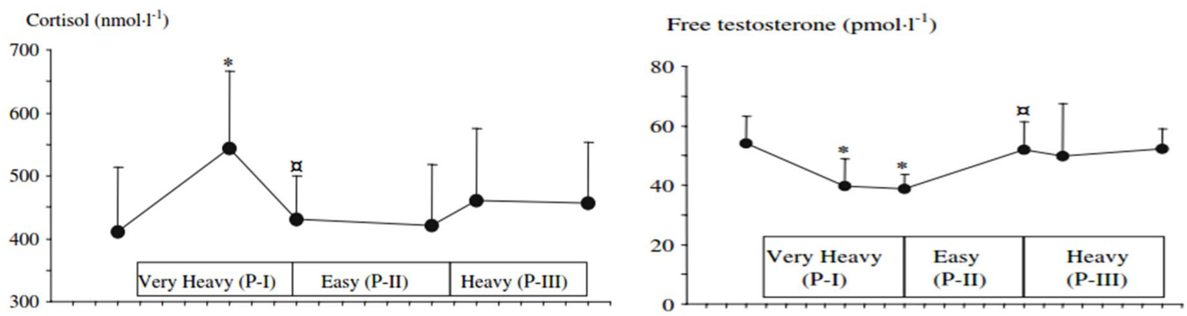

FIGURE 3. Cortisol and testosterone changes during a 20 day military field exercise with changing loads. (Kyröläinen et al. 2008)

Finally, a study by Tanskanen et al. (2011) looked at the association between hormones and overreaching during an 8 week basic training period in the Finnish military. They found that SHBG levels were elevated before training, after 4 weeks, and again after 7 weeks of training. A study by Nindl et al. (2003) found that SHBG levels increased after a period of heavy training. McCaulley et al. (2009) also demonstrated elevated SHBG levels after strenuous training.

5 SHOOTING PERFORMANCE IN SOLDIERS

5.1 Basic concepts of shooting

The two most common positions for shooting are either standing upright or shooting while prone (Figure 4). Tharion et al. (1997) demonstrated that shooting from a prone position is more accurate compared to shooting from a standing position. When shooting from a prone position, the rifle weight does not need to be supported by the muscles of the arms, shoulders and back. When firing multiple shots, such as a set of 10 shots, the fatigue accumulated from holding the rifle and from previous exercise can have a detrimental effect on the results attained. The prone position helps to eliminate body sway and allows the heart rate to recover to resting levels quicker because the heart does not need to work against gravity to supply blood and oxygen to the head. (Tharion et al. 1997.) Shooting prone is more accurate than shooting in a standing position. However, after a bout of heavy exercise, shooting performance can be disrupted even in the prone position (Niinimaa & McAvoy 1983; Tharion et al. 1997). The results from the study by Tharion et al. (1997) demonstrate that soldiers should shoot from a prone position whenever possible.

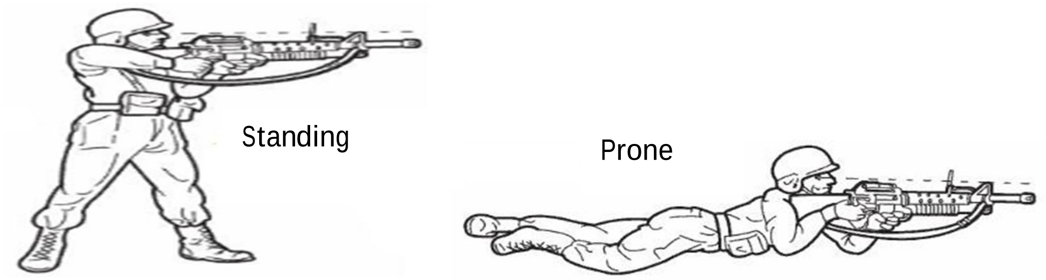

FIGURE 4. The two most common shooting positions (Elliott 2011)

Accurate shooting is a skill that is critical for the survival and success of the soldier on the battlefield. The US Army Field Manual teaches how important correct breath control is in accurate shooting performance. The trigger should be squeezed during the natural respiratory pause which occurs at the maximal exhalation. This technique helps control the barrel movement and thus increases the accuracy of the shot. Also, controlling the motion of the weapon is a central part of good marksmanship and an elevated heart rate can pose a challenge to the shooting accuracy of a soldier. Soldiers are required to move on the battlefield, and maximizing shot accuracy in a state of an increased heart rate and fatigue is important. (Frykman et al. 2012.)

5.2 Exercise induced fatigue and its effects on shooting performance

Fatigue influences perceptual motor performance. Table 6 highlights some of the factors discussed in this chapter which affect shooting performance. Perhaps the best examples of the effects of fatigue on shooting accuracy come from biathlon shooting. A study by Vickers and Williams (2007) showed that after exercising at an intensity of 55% of their maximal oxygen uptake (VO_2 max), the athletes shot with the best accuracy. At a non-exercise pretest level, the shooting accuracy was not as good as at 55% of their VO_2 max level, and at higher levels of exercise such as 100% of their VO_2 max, results showed a decline in the shooting accuracy. (Vickers & Williams 2007.) Since there is scarce information regarding the effects of exercise induced fatigue on the real battlefield, these results provide insight into the relationship between fatigue and shooting accuracy in soldiers (Nibbeling et al. 2014).

TABLE 6. Factors affecting the shooting performance

	Shooting Performance
Standing	· Not as accurate as prone (Tharion et al. 1997) · Shooting accuracy more sensitive to fatigue compared to prone (Hoffman 1992)
Prone	· Most accurate position (Tharion et al. 1997) · Accuracy can be disrupted by preceding heavy exercise (Niinimaa & McAvoy 1983)
Exercise intensity	· 55% of VO_2 max best (Vickers & Williams 2007)
Manual work	· Accuracy not affected but precision yes (Frykman 2012) · After 3 minutes shooting performance recovers (Frykman 2012)
Marching	· Under heavy load carriage there is a detrimental effect on shooting (Knapik et al. 1990; Thario & Moore 1993)
Anxiety	· Added anxiety has a detrimental effect on shooting (Nibbeling et al. 2014; Nieuwenhuys et al. 2012)
Sleep deprivation	· Negatively effects shooting performance (Haslam 1982) · Time to sight target also increases (Haslam 1982)

Hoffman et al. (1992) also studied biathlon shooting performance after exercise at different intensities. The aim of the study was to see how the intensity of exercise prior to the shooting performance affected the shooting accuracy. The results showed that exercise intensity affected the accuracy of the shots that were fired from the standing position but the intensity had no effect on the accuracy of the shots that were fired from the prone position. (Hoffman et al. 1992.) Again biathlon can only be used to speculate what changes might occur in a soldier's shooting ability as a result of fatigue induced by different exercise loads. However, since actual evidence from the battlefield is nearly impossible to collect, it can be hypothesized that shooting from a standing position would be more affected by fatigue than shooting from a prone position.

In yet another study, Frykman et al. (2012) evaluated the impact of fatiguing manual work on a structured marksmanship test. Subjects performed manual work either with or without a body load (Figure 5). In the loaded condition, the added load to the body was 29.9kg and the manual work performed consisted of lifting a box weighing 20.5kg onto a platform that was 155cm high. The subjects were instructed to continue lifting at a pace of 12 lifts per minute until they could no longer maintain that pace. Immediately after completing the lifting task, the subject commenced with the shooting task. The subjects fired at targets simulated to be 150m away from a kneeling unsupported firing position. Eight targets were presented every minute and this lasted for 10 minutes. Subjects were told to shoot as accurately and quickly as possible. The results of this study showed that accuracy was not affected by the added load but precision was impaired when the body load was added. Therefore, from a distance of 150m, the subjects were able to hit the target in both conditions but the precision of the shots relative to each other was not as good with the added load. The increase in dispersion can become a problem with longer target distances because bullet dispersion varies in direct proportion to the distance of the target. This study produced another important result because it also demonstrated that after three minutes of shooting, which was also three minutes of recovery from the manual labor, the shooting accuracy and precision were fully restored. (Frykman et al. 2012.)

FIGURE 5. Manual work was performed with body load, right picture or with no body load, left picture. (Frykman et al. 2012).

Knapik et al. (1990) reported that rifle shooting accuracy was significantly impaired after a foot march in which soldiers had to carry heavy loads. The decline in the shooting accuracy was explained by the increased sway of the rifle in the vertical direction. One possible reason for this was that carrying a backpack weighing 45kg would have tired the muscles of the upper body, especially the muscles which stabilize the arms vertically. Tharion and Moore (1993) reported similar findings in their study, in which soldiers first marched for up to 4 hours while carrying a 45kg weight and then took shots that simulated shooting at a target 100m away with a Noptel ST-1000 marksmanship simulator (Figure 6). The combination of shot accuracy and speed were used to evaluate the shooting performance. When shooting for accuracy, a reduction of up to 42% was observed after the exercise bout. Similar to other studies, the sighting time of the target was also significantly worse in the fatigued state. (Tharion & Moore 1993.)

FIGURE 6. Noptel shooting system (Noptel 2014.)

5.3 Multistressor environment and its effects on shooting performance

Studies have been conducted to determine how anxiety evoked by a multistressor environment affects shooting performance. High levels of anxiety have been observed in soldiers when they are under fire from the enemy and are required to shoot back (Nibbeling et al. 2014; Nieuwenhuys & Oudejans 2012). A study on police officers by Nieuwenhuys and Oudejans (2012), observed how police officers reacted to an opponent in a video lab setting in which the opponent either surrendered or aimed a gun at the officer, in which case the officer was instructed to fire back at the opponent. The results from this study indicated that the police officers were more likely to shoot a surrendering opponent if anxiety was added by an actual stimulation of a hit that caused a painful sensation. This study showed that added anxiety can have a detrimental effect on decision making and perceptual motor performance. The study also reported that officers shot less accurately when they were anxious. (Nieuwenhuys & Oudejans 2012.)

Nibbelling et al. (2014) studied the effects of combined anxiety and exercise induced fatigue on the soldiers' perceptual-motor performance. The setting in their study closely resembled that of a real military operation (figure 7). Studies on performance loss on real battlefields are basically nonexistent because of the high risk of injury or death (Lieberman et al. 2006; Nibbeling et al. 2014). Nibbeling and his group (2014) had Dutch infantry soldiers perform a field track that was set in a military training village. The track included shooting tasks that were performed under low and high anxiety and with preceding heavily fatiguing running exercises to induce moderate fatigue. The goal of the shooting tasks was to assess accuracy and decision making of whether to shoot or not. The results from this study indicated that anxiety can lead to a reduction in the shooting performance, and in a high anxiety situation the reduction in shooting accuracy was between 20% and 40%. Soldiers in this study made an error in deciding whether to shoot or not only 1% of the time when under low anxiety, and 4% of the time when under high anxiety. Shooting accuracy was demonstrated to be more sensitive to anxiety compared to fatigue in this study, which could be explained by the moderate level of fatigue that was experienced by the subjects. However, the precise combat situation cannot be experimentally simulated. (Nibbeling et al. 2014.)

FIGURE 7. The pictures show the opponent in the shooting task either surrendering right picture or pointing his weapon to shoot left picture. (Nibbeling et al. 2014).

Sleep deprivation also negatively impacts shooting performance. Haslam (1982) demonstrated that sleep deprivation significantly decreased marksmanship accuracy and also increased the time to sight a target. He reported that infantrymen shooting from the prone position hit 25% less pop-up targets when deprived of sleep for more than 48 hours. (Haslam 1982.) In a similar study, Haslam and Abraham (1987) demonstrated that soldiers who were sleep deprived for 90 hours did not show any reduction in accuracy when firing at stationary targets with no time constraints. However, in the same study, the shooting accuracy declined by 10% when compared to the baseline levels for targets appearing at random locations on the firing range.

Several 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. Fatigue has also been indicated as a significant factor affecting marksmanship. In addition to anxiety and fatigue, sleep deprivation has been shown to have a detrimental effect on the shooting accuracy. Research on how prolonged combat training in a multistressor environment affects the soldiers shooting performance is lacking.

6 PURPOSE OF THE STUDY

The purpose of the present study was to examine the changes in the muscle strength, serum hormone concentrations and shooting accuracy in conscripts over a prolonged combat training period.

The research problems and hypotheses were as follows:

1) How are the strength levels for lower extremities and upper body affected by the changing loads during the prolonged combat training period?

Hypothesis: The strength levels for lower extremities and upper body will decrease as the training load increases.

Previous literature has shown that strength levels decrease during both short and long lasting military training periods (Nindl et al. 2002; Nindl et al. 2007). More specifically, literature has shown that decreases in strength can be limited to only upper body (Legg & Patton 1987; Knapik et al. 1990) or lower body (Hackney et al. 1991; Nindl et al. 2002). These different findings suggest that decreases in strength are seen in the muscles which are loaded during the training period (Nindl et al. 2002).

2) How is the shooting performance from a standing and a prone position affected by the changing loads during the prolonged combat training period?

Hypothesis: The shooting performance will be negatively affected as a result of fatigue when the loading is high. However, shooting from a standing position will be more affected since shooting from a prone position does not require similar effort from muscles of the upper and the lower body.

Knapik et al. (1990) has shown that shooting performance is sensitive to fatigue. As muscles get fatigued, there is an increase in the vertical sway of the rifle which negatively affects the shooting score. When shooting from a prone position, fatigue does not play such an important role because the weapon is supported against the ground. (Niinimaa & McAvoy 1983; Tharion et al. 1997; Knapik et al. 1990.)

3) How are serum hormone concentrations affected by the changing loads during the prolonged combat training period?

Hypothesis: Serum cortisol and SHBG concentrations will increase with increasing load, while serum testosterone concentrations will decrease with the increasing loads.

Previous studies have demonstrated that serum cortisol concentrations increase during strenuous military training (Friedl et al. 2000; Kyröläinen et al. 2008). Serum SHBG concentrations have also been shown to increase during different durations of military training (Friedl et al. 1995; Tanskanen et al. 2011). Serum testosterone concentrations have been shown to decrease during strenuous military training (Friedl et al. 2000; Kyröläinen et al. 2008).

4) Is there any association between the changes in the strength levels, shooting scores and hormonal concentrations?

Hypothesis: The strength levels will show a positive correlation with the shooting score.

Shooting score has been shown to decrease in a state of fatigue (Knapik et al. 1990). Therefore, it is expected that if the strength levels decline so will the shooting score.

5) Is the resting period at the end of the prolonged combat training period sufficient for the strength levels, shooting scores and hormonal concentrations to return to baseline levels?

Hypothesis: Five days of rest at the end of the prolonged combat training period will be sufficient for the strength, shooting and hormone levels to return to baseline levels.

Earlier findings suggest that reducing the load during a combat training period, enables serum testosterone and serum SHBG to return to baseline levels promptly. However, serum cortisol concentrations may require a longer period to return to baseline levels. (Friedl et al. 1995.)

7 METHODS

7.1 Subjects

The subjects in this study were 19-22 year old male conscripts. From the beginning of the study, 61 individuals were involved. However, at various points 12 individuals dropped out. The primary reasons they gave for dropping out included discomfort of having to give blood samples and the lack of motivation. Therefore, 49 conscripts completed the study as subjects. Before the study began, all the conscripts were informed of the experimental design and the possible risks that could be associated with it. Subjects were informed that they could drop out of the study at any stage if they so wished. Every subject was required to provide a written consent before the study commenced. The study was approved by the Finnish Defense Forces. Ethical approval was also granted by Keski-Suomen sairaanhoitopiiri.

TABLE 7. The baseline values of the subject population (n=49).

Age	19.7 (±0.7)
Height (cm)	179.1 (±7.2)
Body Mass (kg)	73.0 (±8.8)
Body Fat %	12.6 (±4.9)

7.2 Experimental design

The study took place in May and June of 2015. It lasted for 37 days. The first part of the study consisted of a control period during which the conscripts spent 11 days at the army barracks, excluding a weekend which they spent at home. The following 21 days was the prolonged combat training period, which was further divided into the shooting camp (5 days), combat camp 1 (CC1) (8 days) and combat camp 2 (CC2) (8 days). After the prolonged training camp the subjects had 5 days to recover.

Control period. There was no separate control group in this study. Therefore, the 11 days spent at the barracks were used as the control period. Figure 8 illustrates the different phases of the 37 days of the study period.

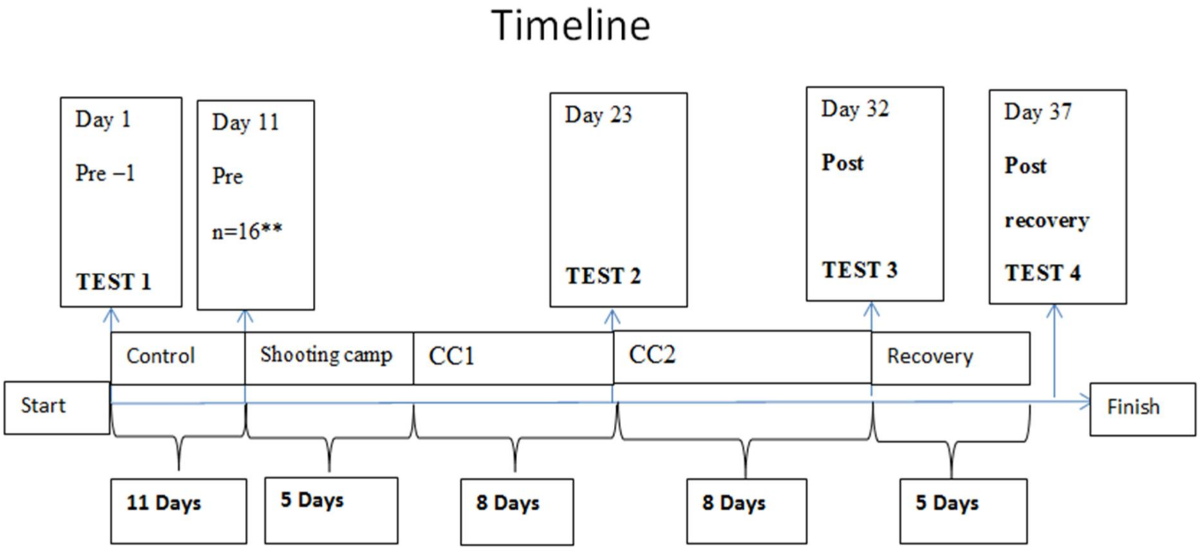

FIGURE 8. The experimental design showing the 37 day study and the test dates. Test 1, 2, 3, and 4 consisted of isometric strength test for the upper and the lower extremities, the shooting test and blood sample collection. ** Day 11 only 16 subjects participated in the strength and the shooting tests.

Shooting camp. The first 5 days of the prolonged training period were spent at a shooting camp. At the shooting camp, the goal was for each conscript to improve their shooting skills and advance their weapon handling abilities. Daily programs lasted from 7am to 5pm, after which the conscripts had time to rest and service their equipment. During the shooting camp, the objective was not to exhaust the conscripts but rather to ensure that each of them maintained a high level of performance by ensuring that they had appropriate rest and sleep.

CC1and CC2. The 16 days that followed included CC1 and CC2 which were meant to simulate a modern day war situation. During CC1, subjects had to familiarize themselves with the environment where the war simulation would take place during CC2. They had to set up their base and identify their defensive and offensive positions, as well as practice moving from their base to their attacking positions. Surveillance and guarding of the base around the clock were mandatory throughout CC1 and CC2. The loading during CC1 was high because subjects had to prepare and be ready for CC2. Over 5000 soldiers participated in the national war simulation, which for the subjects of this study represented CC2. The specific task of the conscripts in this study was to operate as an offensive unit during CC2. The loading during CC2 was not predictable because it depended on how the war simulation would have played out.

Recovery. After the prolonged training period, the subjects had five days of recovery time, three at the army barracks and two at home before the final measurements were taken. The purpose of this recovery period was to determine whether the conscripts could fully recover from the strenuous 21 day training period in a short period of time. Figure 8 shows the experimental design and the duration and timing of each stage and each specific test that was performed at each of the different time points.

7.3 Measurements

Figure 8 shows the different days when each of the measurements were taken. There were a total of six major testing days which included the body composition measurement, blood sample, strength measurement and the shooting accuracy test. Further tests were also carried out such as a balance test, saliva sampling, fitness tests including sit ups, push ups and a 3km march, however this thesis does not discuss the data from those tests.

The body composition measurements were conducted between 6am - 7am at each time point. The blood samples were taken between 6.30am - 7.30am at each testing point to account for diurnal variation in hormone concentrations. The strength and the shooting tests were performed between 11.00am - 13.30pm at each testing point. The order of measurements was body composition, blood sample, shooting, upper body strength and lower body strength. All the tests were conducted under the supervision of the same personnel at each testing point.

7.3.1 Body Composition

The InBody- 720 analyzer (Biospace Co. Ltd., Seoul, Korea) was used to measure the body composition. The measurement was taken after 12 hours of fasting, between 6am - 7am. The subjects were instructed not to eat anything after their evening meal which was around 7pm. With regards to this thesis, the subject’s weight was the variable of interest from the body composition test.

7.3.2 Strength Measurements

An isometric leg press was used to measure strength changes in the lower extremities. The measurements were conducted using a leg extension dynamometer manufactured by the University of Jyväskylä, Finland, Department of Biology of Physical Activity (Figure 9). The knee angle for the subjects was set at 107 degrees (Häkkinen et al. 1998). The 107 degree knee angle was measured using the trochanter major and the lateral malleolus as reference points. The subjects were allowed one familiarization attempt before two actual test performances were executed. A one minute rest separated each attempt. They were instructed to push as hard as they could. They were told to ensure that they keep contact with the seat and the backrest during the performance. Vocal encouragement was provided by the supervisors for every test performed and for each subject. The best result out of the two was recorded for later statistical analysis.

FIGURE 9. Isometric leg press manufactured by the University of Jyväskylä, Department of Biology of Physical Activity

FIGURE 10. Isometric bench press manufactured by the University of Jyväskylä, Department of Biology of Physical Activity.

An isometric bench press was used to measure strength changes in the upper extremities. The measurements were conducted using a seated bench press manufactured by the University of Jyväskylä, Finland, Department of Biology of Physical Activity (Figure 10). The equipment was adjusted for each subject so that the arms were parallel to the floor and the elbow angle was approximately 90 degrees (Häkkinen et al. 1998). The subjects were allowed one trial attempt before two actual test performances were conducted. A one minute rest separated each of the attempts. Similarly, for the leg press procedure, the subjects were instructed to push as hard as they could. Vocal encouragement was provided by the testing personnel. The best result out of the two was recorded for later statistical analysis.

7.3.3 Shooting

The shooting tests were performed from both prone and standing positions (Figure 11). First the conscripts were told to fire 10 shots at the target from a prone position and then were told to fire 10 shots at the target from a standing position. The best possible score from the 10 shots was 100, and the result for each conscript was given at an accuracy of 0.1. The shooting tests were performed indoors and the target was 10 meters away in both the prone and standing positions. The 10 meter distance simulates a distance of 150m in real life.

The shooting tests were performed using Eko-Aims weapons (Eko-Aims OY, Ylämylly, Finland). The weapon used in the test was similar to the RK 95 which the conscripts handled daily. The laser system which the Eko-Aims weapons uses, allowed the tests to be performed indoors without the risk factors and safety measures that would have been required if real shots were fired outdoors at a shooting range. Because the tests were performed indoors the lighting and wind could not affect the results. The system provided immediate feedback to the person conducting the test. The sum of the ten shots from each position was recorded and later used for statistical analysis of the results.

FIGURE 11. Prone position and standing position used for the shooting test.

The blood samples were taken at six different time points during the study. Each blood sample was taken between 6.30am - 7.30am to avoid for diurnal variation in hormone concentrations. Testosterone, cortisol and SHBG were the three different hormones analyzed from the blood samples. All blood samples were collected by professional health care personnel in an indoor setting. The blood samples were taken from the antecubital vein. The samples were frozen and transported to University of Jyväskylä Department of Biology of Physical Activity laboratories for later analysis. Before the analysis, the blood samples were thawed and then centrifuged (Megafure 1.0 R Heraeus, DJB Lab Care, Germany) at 3.500 rpm for 10 minutes. The sensitivity and the inter-assay coefficients of variance for these assays were 0.5nmol/l and 10.9% for testosterone, 5.5nmol/l and 5.9% for cortisol, 0.2 nmol/l and 7.2% for SHBG.

7.3.5 Loading

Physical loading was monitored using (Hookie AM20, Traxmeet Ltd, Espoo Finland) accelerometer (figure 12). The device was attached to the waist with an elastic belt. The device calculated the total number of steps taken during each day. The subjects were instructed to keep the accelerometer on them at all times.

FIGURE 12. Hookie accelerometer used for measuring the loading (Traxmeet 2012.)

7.3.6 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 the next morning the previous diary was collected and a new one issued. Relevant to this thesis was the amount of time that each conscript slept each night and the stress levels. The subjects were asked to write down how many hours they slept each night to the nearest a half an hour (for example 7.5 hours). The stress levels were measured on a scale of 0-5. Zero meaning not stressed at all and 5 meaning extremely stressed.

7.4 Statistical analysis

The data for the present study was analyzed using SPSS Statistics v.20 Computer Software as well as Microsoft Excel. For calculating means, standard deviations (SD), and standard error (SE) conventional statistical methods were used. A general linear model, with repeated measures ANOVA was used to analyze the differences between the four different measuring points with four levels (Day 1, Day 23, Day 32, and Day 37). Bivariate correlation was used for correlation analysis where the changes in the variables between the different time points were tested. Statistical significance values were set at $*p \leq 0.05$, $**p \leq 0.01$ and $***p \leq 0.001$ for all tests.

8 RESULTS

8.1 Maximal strength

Isometric leg press. Significant increases in leg isometric force were noted from Day 23 of 347kg (± 93) to that of 359kg (±102) (p≤0.05) on Day 32 (Figure 13.) No significant changes occurred in leg isometric force from Day 1 to Day 23 and from Day 32 to Day 37.

Isometric bench press. Upper body isometric bench press force increased significantly from Day 1 of 91kg (±18) (p≤0,001) to that of 95kg (±19) p≤0,001) on Day 23 (Figure 14.) The increase from Day 1 to Day 23 was 4.6% (±5.4). A significant decline of 2.6% in strength occurred from Day 23 to Day 32 (p≤0,001). From Day 32 to Day 37 a significant decrease of 2.6% ±3.9 in force was observed.

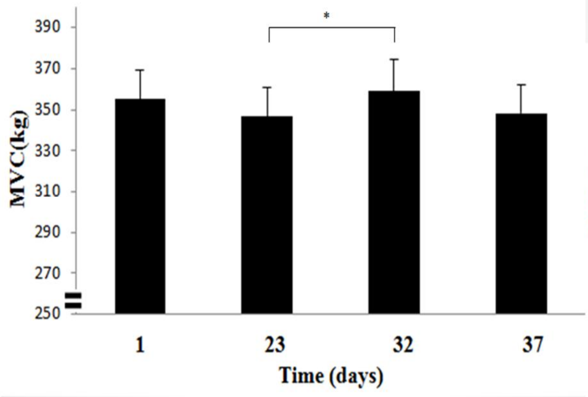

FIGURE 13. MVC (mean ±SE) in leg press during the study period. *p≤0.05.

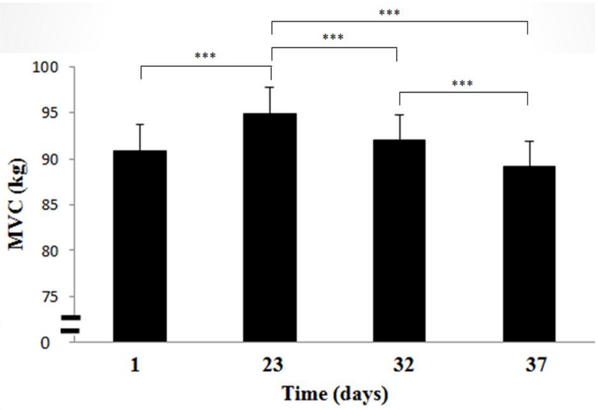

FIGURE 14. MVC (mean ±SE) in bench press during the study period. *** p≤0,001.

8.2 Shooting

Shooting standing and prone. There was a significant decrease in the shooting in a standing position score from Day 1 (58.5 ±12.4 points) to (45.0 ±10.1 points (p≤0.001) on Day 23 (Figure 15.) The decline was 19% ±26.9. Between Day 23 and Day 32 a significant improvement of 45.8% ±40.3 was observed. From day 32 (62.2 ±10.9 points) to Day 37 (55.8 ±14.4 points, p≤0.05) a significant reduction in the shooting score was noted.

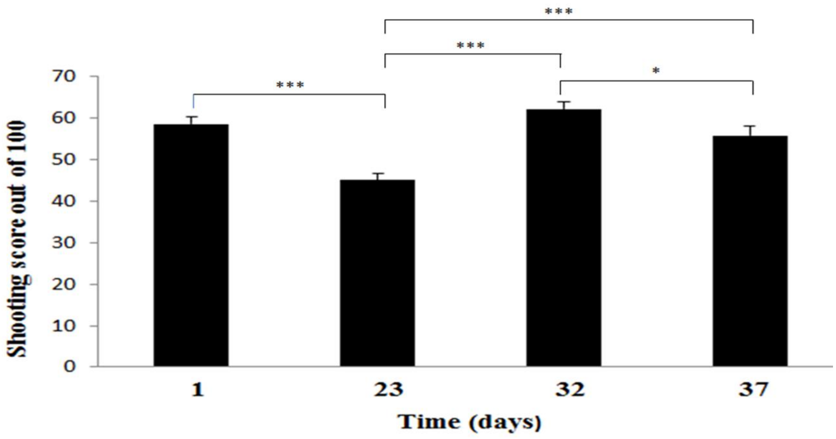

FIGURE 15. Shooting standing score (mean ±SE) expressed as absolute values during the study period. *p≤0.05, *** p≤0,001.

8.3 Serum hormone concentrations

Cortisol. A significant increase of 26.6% ±32.5 in serum cortisol concentrations was observed from Day 1 (319.0nmol/l ±73.6) to Day 32 (397.1nmol/l ±70.0 p≤0.001) (Figure 16.) From Day 1 to Day 37 a significant increase of 20.8% ±30.5 p≤0.001 was observed as well as from Day 23 to Day 32 (15.3% ±27.7 (p≤0.05.)

Testosterone. Serum testosterone concentrations decreased significantly by 25.9% ±25.6 from Day 1 (18.5nmol/l ±4.2) to Day 23 (13.5nmol/l ±4.6 p≤0.001) (Figure 17.) A significant increase of 25.9% ±50.2 (p≤0.01) was observed from Day 23 to Day 32 as well as from Day 32 to Day 37 (29.6% ± 27.9 (p≤0.001.)

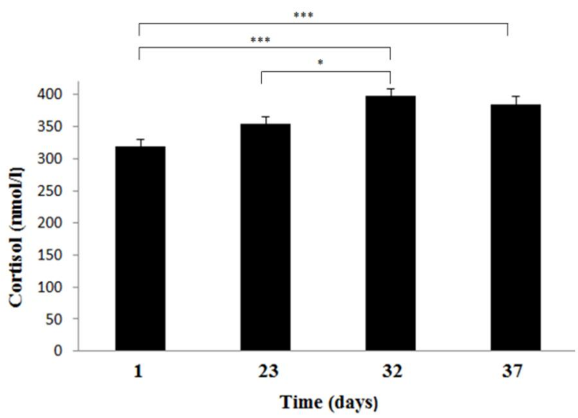

FIGURE 16. Serum cortisol levels (mean ± SE) during the study period. *p≤0.05, ***p≤0.001.

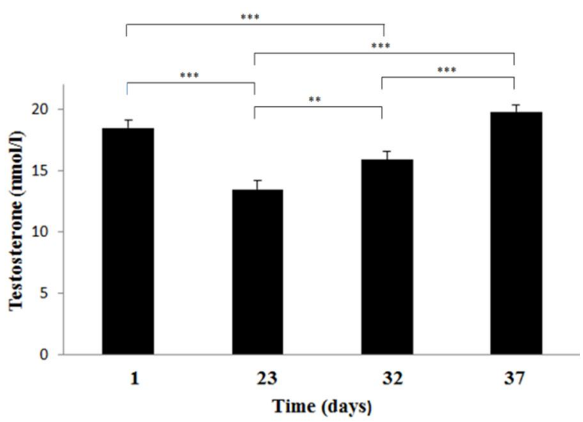

FIGURE 17. Serum testosterone levels (mean ± SE) during the study period. **p≤0.01, ***p≤0.001.

SHBG. A significant decrease of 9.7% ±23.4 in serum SHBG concentrations was observed from Day 1 (37.6 nmol/l ±10.5) to Day 23 (32.5 nmol/l ±8.1 p≤0.001) (Figure 18.) Between Day 32 and Day 37 there was a significant decrease of 6.7% ±10.0 (p≤0.001).

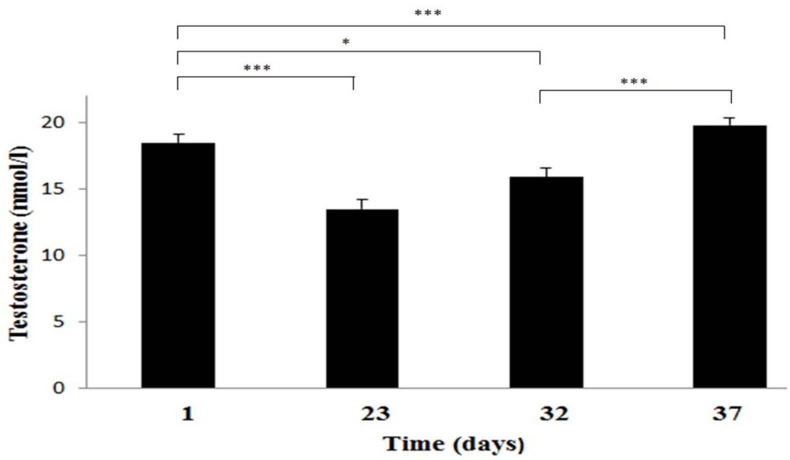

FIGURE 18. Serum SHBG concentrations (mean ±SE) during the study period. *p≤0.05, ***p≤0.001.

8.4 Physical Loading

Figure 19 shows the changes in loading during the prolonged combat training period. During the shooting camp and the CC1 the average number of steps taken by conscripts during each day was 14134. During the CC2 the average number of steps taken by the conscripts each day was 11569.

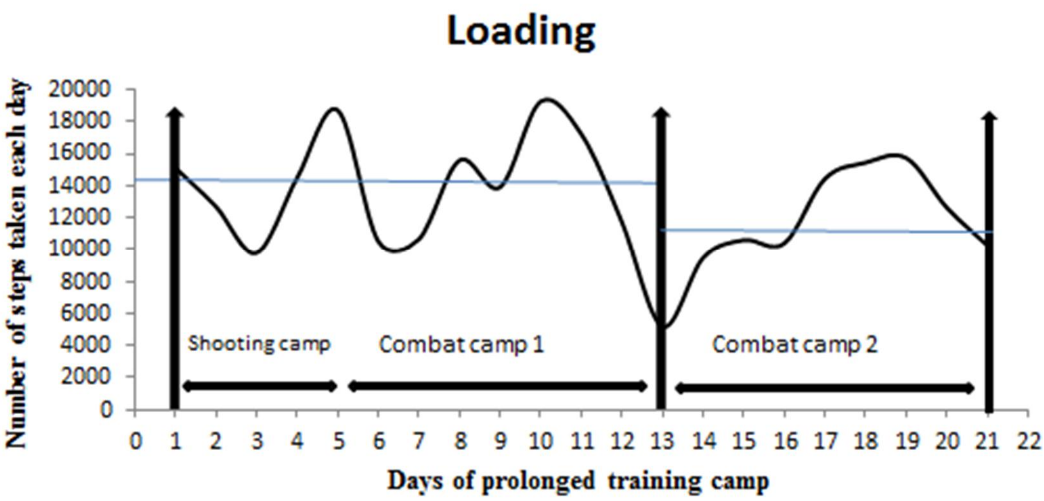

FIGURE 19. Loading of the conscripts measured in steps taken during each day. The vertical line on day 12 represents Day 23 measuring point and the vertical line on day 21 represents Day 32 measuring point.

8.5 Sleep and stress levels

During the entire prolonged combat training period the average amount of sleep per night was 6.1 ±0.9 hours. Figure 20 shows the fluctuations in the stress levels during the prolonged combat training period. The stress levels did not show any significant fluctuations from the shooting camp and CC1 to CC2 as the average stress index dropped from 0.51 ±0.2 to 0.50 ±0.2.

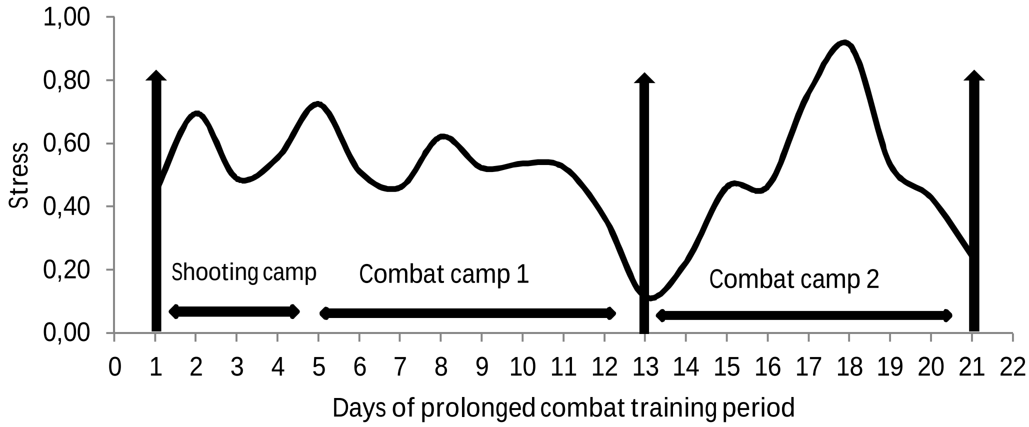

FIGURE 20. Fluctuations in the stress levels during the prolonged training period. The vertical line on day 12 represents Day 23 measuring point and the vertical line on day 21 represents Day 32 measuring point.

8.6 Correlations

Leg Strength and shooting. Figures 21, 22 and 23 show the correlation between shooting standing and leg strength. There was a significant positive correlation between the changes in leg strength from Day 1 to Day 23 and the change in shooting standing score from Day 1 to Day 23, ($r=0.324$, $p\leq0.05$). The change from Day 23 to Day 32 also showed a significant positive correlation between the shooting score and the leg strength, ($r=0.337$, $p\leq0.05$). A significant correlation was observed between the change in shooting standing score from Day 32 to Day 37 and the change in leg strength from Day 32 to Day 37 ($r=0.463$, $p\leq0.001$).

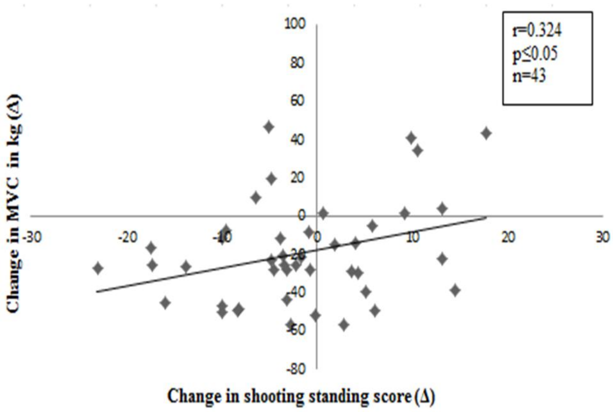

FIGURE 21. Correlation between the changes in shooting standing and the changes in leg strength between Day 1 and Day 23.

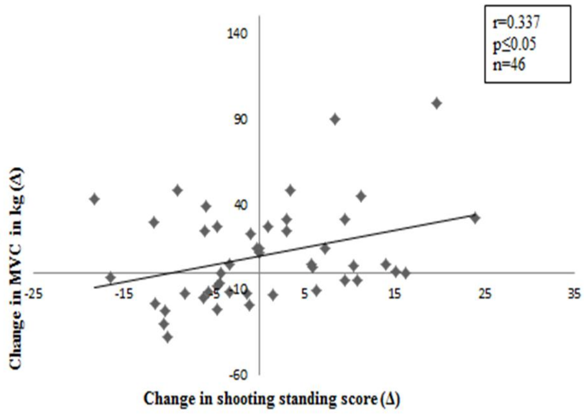

FIGURE 22. Correlation between the changes in shooting standing and the changes in leg strength between Day 23 and Day 32.

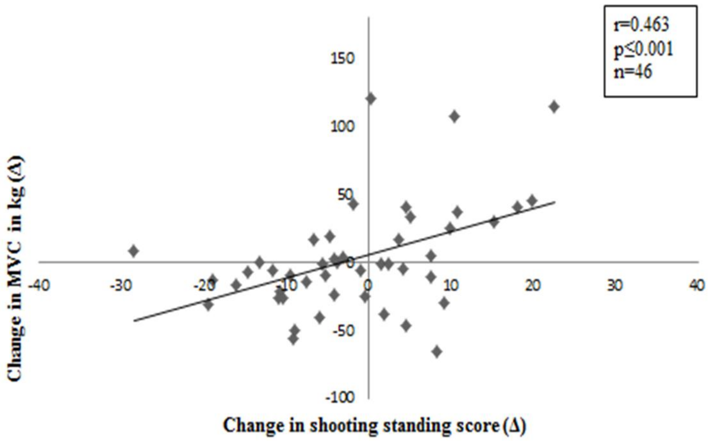

FIGURE 23. Correlation between the changes in shooting standing and the changes in leg strength between Day 32 and Day 37.

Upper body strength and shooting. Significant correlations were observed between the changes in upper body strength and shooting standing performance. The change in upper body strength from Day 1 to Day 37 showed significant positive correlations with the change in shooting standing performance from Day 1 to Day 37, (r=0.330, p≤0.05). The change in upper body strength from Day 1 to Day 32 was correlated with the change in shooting standing performance from Day 1 to Day 32. However, this correlation was not statistically significant, (r=0.259, p≤0.090).

Cortisol and shooting. Figure 24 shows a significant correlation between the changes in serum cortisol concentrations from Day 1 to Day 23 and the change in shooting standing score from Day 1 to Day 23, (r=0.386, p≤0.05).

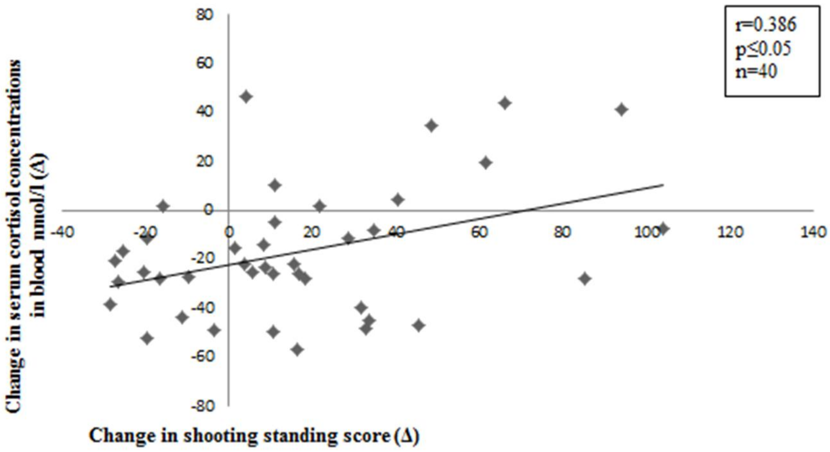

FIGURE 24. Correlation between the changes in cortisol and the changes in shooting standing between Day 1 and Day 23.

8.7 Control Period

Control Period. Table 8 shows the mean values that occurred in shooting performance, while table 9 shows upper and lower body isometric force values and table 10 serum hormone concentrations.

TABLE 8. Shooting standing and shooting prone scores during the control period. All values expressed as absolute values. $^{**}p \leq 0.01$ refers to significant differences between Pre -1 and Pre. (n=16)

Shooting position	**Pre -1 (points)**	**Pre (points)**	**Δ (%)**	**p-value**
Standing	59.6 (±11.3)	68.7 (±8.5)	18.4 (±22.2)	0.01 **
Prone	87.1 (±7.4)	85.3 (±11.0)	-2.3 (±8.6)	0.310

TABLE 9. Strength levels during the control period.

Strength	**Pre -1 (kg)**	**Pre (kg)**	**Δ (%)**	**p-value**
Legs	344 (±101)	335 (±103)	-2.7 (±7.9)	0.179
Upper body	86 (±13)	85 (±13)	-0.3 (±4.6)	0.608

TABLE 10. Serum hormone and SHBG concentrations during the control period. ***p≤0.001 refers to significant differences between Pre -1 and Pre. (n=16)

Hormone	Pre -1 (nmol/l)	Pre (nmol/l)	Δ (%)	p-value
Cortisol	324.0 (±53.2)	319.7 (±94.2)	-1.5 (±23.5)	0.824
Testosterone	18.2 (±4.1)	17.7 (±4.3)	-1.0 (±19.6)	0.581
SHBG	35.9 (±11.0)	28.4 (±8.6)	-19.3 (±14.8)	0.001***

9 DISCUSSION

The present study investigated strength levels, shooting performance and hormonal responses in conscripts during a prolonged military training period. The main findings from the study were:

1) Leg strength decreased as the load increased towards Day 23. As the load decreased after Day 23, there was a significant improvement in leg strength on Day 32.
2) The shooting score from a standing position decreased significantly between Day 1 and Day 23. Between Day 23 and Day 32 the shooting performance improved significantly. The shooting prone score did not show any significant changes during the entire study period.
3) Serum cortisol concentrations increased from the start of the prolonged training period until the end of the training period. Serum testosterone concentrations decreased from the start of the prolonged training period towards the end of it.
4) Significant positive correlations between changes in shooting standing score and the changes in strength for legs and upper body were observed. The changes in serum cortisol concentrations and changes in shooting standing score also showed significant positive correlations.
5) All the variables monitored except cortisol and SHBG returned to baseline level after the five days of rest.

9.1 Fluctuations in leg strength

It has been previously shown that adequate lower body strength is important for soldiers if they are to perform their duties successfully (Welsh et al. 2008; Kraemer & Szivak 2012). Nindl et al. (2002) demonstrated that after 72 hours of intensive soldier specific training, decrements in lower body ballistic power were noted in soldiers. In another study, it was demonstrated that over an 8-week training period a decline of up to 20% was noted in the soldier’s maximum strength levels (Nindl et al. 2007).

In the present study, the lowest leg strength values were recorded on Day 23. After the completion of the shooting camp and CC1, the Day 23 measurements were done. During the shooting camp and CC1, the loading was higher than during CC2. Four days before Day 23 measurements were the most demanding from a loading perspective during the entire training period. After Day 23, there was a decline in the daily loading of the conscripts and this was shown in the leg strength results, which improved significantly from Day 23 to Day 32.

The present findings suggest that leg strength levels are related to the loads imposed on the conscripts during a prolonged combat training period. The decline in strength levels returned to baseline levels when the loading was reduced during CC2. This suggests that complete rest and a return to the army barracks or home is not a necessity if the goal is to enable the conscripts to recover physically. A decrease in the loading should be sufficient to achieve the complete recovery of strength levels. A study by Kyröläinen et al. (2008) supports this finding, because in that study conscripts had a lighter training period between two more intense training periods. The study showed that a lighter training period in the middle allowed for sufficient recovery of the strength levels and the hormonal concentrations before the commencing of the second heavy training period. (Kyröläinen et al. 2008.)

9.2 Fluctuations in standing shooting performance

There is previous evidence to suggest that performance in shooting is sensitive to fatigue. Knapik et al. (1990) demonstrated that after a foot march with heavy loads, there was an increase in the vertical sway of the rifle when shooting from a standing position. This vertical sway negatively impacted on the shooting score. (Knapik et al. 1990; Tharion et al. 1997.)

The results of the present study support the earlier findings. In this study, the shooting score was not measured after a single heavy event but rather after a period of intense soldier specific training. The shooting standing scores at Day 1 were significantly higher than shooting standing scores at Day 23. As was mentioned, the most demanding part of the prolonged combat training period was during the shooting camp and CC1 and the peak occurred at the very end of CC1. After Day 23, the loading on the conscripts was reduced and this resulted in the shooting standing scores returning to baseline levels.

From a practical perspective, these findings suggest that soldiers should get adequate rest in order for their shooting performance to remain high. Similarly, concerning leg strength, it might not be necessary for the conscripts to get a few days of complete rest. Rather, decreasing the loading on them should be sufficient to ensure that their level of performance returns back to initial levels.

9.3 Changes in prone shooting performance

Previous studies in biathlon have shown that fatigue is more sensitive to shooting when shots are fired from a standing position compared to shots fired from the prone position (Hoffman et al. 1992). Factors contributing to these findings are that when shooting from a prone position, the rifle weight does not need to be supported by the muscles of the arms, the shoulders, and the back and therefore the fatigue of these muscle groups is not as important of a factor in performance. In the prone position most of the weight from the weapon is supported against the ground. (Niinimaa & McAvoy 1983; Tharion et al. 1997.) The prone position also helps to eliminate body sway which contributes to the accuracy of the shots (Tharion et al. 1997).

Despite the changing loads that the conscripts had to endure during the prolonged training period, the shooting prone performance did not show any significant changes during the study period. This finding has some significance for future research in this field. If the purpose of the study would be to determine how strength levels correlate with shooting performance, it might make sense to monitor the shooting standing performance because it is more sensitive to the changes in the loading compared to the shooting prone performance. In this study, significant changes were noted in the shooting standing score between all measuring points, whereas no significant changes were noted in shooting prone scores.

9.4 Hormonal responses during prolonged combat training period

Previous studies have indicated that testosterone levels drop after varying durations of combat training. Friedl et al. (2000) demonstrated an 86% drop in testosterone concentrations during an 8-week study period. Similar to the present study, Kyröläinen et al. (2008) detected a 27% decline in testosterone levels during a 20 day combat training period. The duration of the study by Kyröläinen et al. (2008) was similar to this study and the findings are closely related.

In the present study the decline in serum testosterone concentrations from Day 1 to Day 23 was 25.9%. The loading on the subjects was most intense in the days leading up to the measurements, on Day 23. From Day 23 until the end of the prolonged training period there was a slight increase in serum testosterone concentrations, although they did not recover to baseline level. Similar to the study by Kyröläinen et al. (2008), the present study demonstrated that a reduced loading period enables serum testosterone concentrations to begin recovering toward the baseline levels.

Serum cortisol concentrations have been shown to increase during prolonged combat training period. Friedl et al. (2000) showed that during an 8-week combat training period, cortisol levels increased. Similar to the current study, Kyröläinen et al. (2008) demonstrated that during a 20 day combat training period the cortisol levels increased by 32%.

The results from the present study resemble those of Kyröläinen et al. (2008) because in the present study the cortisol levels were 15.5% higher at Day 23 compared to Day 1. After day 23 the cortisol concentrations continued to rise and were 26.6% higher at day 32 compared to Day 1. The loads leading to Day 23 measurements were observed to be the highest in this study, and afterwards declined until the end of the training period. However, unlike testosterone, strength and shooting values, cortisol concentrations did not begin to recover between Day 23 and Day 32. As a common stress marker, it was not surprising that cortisol levels did not begin to decrease after Day 23. The results from the present study indicate that though the loading was reduced during CC2, the stress levels were at the peak at the end of CC2 when the war simulation reached its point of culmination.

Previous studies have indicated that SHBG concentrations increased as a result of strenuous training (McCaulley et al. 2009). Tanskanen et al. (2011) indicated that SHBG concentrations were elevated at different measuring points during an 8-week study on conscripts. In another study Friedl et al. (1995) observed an increase in SHBG concentrations during 8 weeks of strenuous military training.

The present study recorded the highest SHBG values on Day 1. A possible explanation for this was that the day before the test, the subjects had a physically demanding day. This might have caused the SHBG concentrations to rise (Zmuda et al. 1996; Kraemer & Rogol 2008, 603; McCaulley et al. 2009). The blood samples taken on Day 7 support this argument, because on Day 7, which was immediately before the subjects began their prolonged combat training, serum SHBG concentrations were at the lowest level. From that point on, serum SHBG concentrations rose until the end of the prolonged training camp.

9.5 Relations between strength levels, shooting scores, and hormonal concentrations

Muscle strength and shooting standing. The most significant positive correlation from the present study was noted between the changes in the leg strength and the changes in the shooting standing score. As the leg strength score from Day 1 to Day 23 declined, so did the shooting score. After Day 23, the loading on the conscripts was less and this resulted in an improvement in leg strength, which was also reflected in the shooting standing score.

The current study found a similar positive correlation between the change in shooting standing score and the change in upper body strength from Day 1 to Day 37. The same trend was observed in the change from Day 1 to Day 32 in the shooting standing score and upper body strength but, this correlation was not significant.

These correlations are noteworthy because they demonstrate the impact that declining strength levels can have on a soldier's ability to shoot. However, the present study also supports earlier findings that fatigue is observable in the muscles that are the most stressed. Hackney et al. (1991) and Nindl et al. (2002) both observed a decrease in lower body anaerobic power during a continuous military operation without a change in upper body strength. Legg & Patton (1987) and Knapik et al. (1990) demonstrated a decline in upper body strength but no changes in lower body strength. The contrasting results are likely caused by the differences in the specific activities that the subjects were engaged in during the study period (Nindl et al. 2002). In the present study, the lower extremities were more stressed, because the changes in the upper body strength, though significant, were minimal between the different time points.

Cortisol and shooting standing. A significant positive correlation was observed between the change in the serum cortisol concentrations and the change in shooting standing score from Day 1 to Day 23. The shooting standing performance of the soldiers decreased as the loading increased from Day 1 to Day 23 while serum cortisol concentrations increased during the same time period. The results from the present study suggest that the decreases in shooting standing performance could be predicted if cortisol levels rise in conscripts.

9.6 Recovery of strength levels, shooting scores, and hormonal concentrations

From the variables monitored only serum cortisol did not return to baseline levels after the five days of recovery. In the strength levels as well as the shooting scores, there were no significant differences between the baseline scores and the post recovery scores. From this information it can be concluded that the five days were sufficient to aid in the complete recovery in the strength and shooting performance of the conscripts.

Serum cortisol and SHBG concentrations were the only variables measured which showed significant changes from the baseline measurements to post recovery measurements. Serum SHBG concentrations were elevated from the start of the study. However, if the test values obtained on Day 7 were used as the baseline there would have been no significant differences in the baseline and post recovery concentrations. For serum cortisol concentrations, more time may have been required to return to baseline values. A study by Friedl et al. (2001) demonstrated similar findings; it lasted for 8 weeks, and week 5 was a recovery week. After the 8 weeks, a 5-week recovery period was provided before the final measurements were taken. Findings from that study indicated that testosterone returned to baseline levels promptly during the 5^{th} week and were similar to baseline values at the final measurements. However, the relevant finding was that cortisol concentrations did not return to baseline levels during the recovery week 5, but rather a longer period of several weeks was required for the baseline concentrations to be attained. (Friedl et al. 2001.)

Practically, the results suggest that five days are adequate for the complete recovery in all variables except for cortisol after a prolonged combat training period. Further studies could be conducted to determine whether one, two, or three days would suffice.

9.7 Strengths and limitations of the study

Strengths of the study. The strength of having conscripts as subjects was that all the subjects were in the same place and performed similar duties during the study period. In the present study, this increased the reliability of the results, because during the prolonged training period, the researchers were in contact with the subjects every day and followed their training. The researchers were able to monitor the kind of loading that the subjects were under during the prolonged combat training period.

Limitations of the study. One limitation of the present study was that only 16 subjects completed the control measurements. The low number of subjects available for the control measurements was due to the fact that the majority of them had traveled to their homes on that day. Having all the conscripts participate in the control measurements would have increased the reliability of the control period. Another limitation of the present study was that the rest period at the end of the study was not monitored, since subjects were at home during the five-day recovery period. In future studies, the staying of the conscripts at the army barracks would enable the researchers to monitor the loads during the recovery period.

Another limitation of the present study was that during CC2 the loads imposed on the subjects were lower than expected. This decline in loading was due to several factors, the most relevant of which was that over 5000 soldiers participated in the final exercise. The effect that this large number had on the subjects of this study was that they had to react to the developments of the other units involved in the war simulation. Events unfolded in a manner that left the subjects of the present study with very little to do during CC2. This decline in the loading meant that the physical challenge encountered during this time period was lower than what was expected at the start of the study. In future studies, it would be easier to control the loading of the subjects while undergoing an independent combat training camp.

10 PRACTICAL APPLICATION AND CONCLUSION

The present study showed that a prolonged combat training period has adverse effects on the strength levels and the shooting ability in soldiers. Therefore, ensuring that soldiers 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.

In conclusion, it should be noted that the subjects of this study were conscripts who were completing their military service. Many studies in this field have investigated professional soldiers and this should be considered if the aim is to compare these findings with results attained from studies with professional soldiers as subjects. The major findings from the present study were that the changes in strength levels for the legs were correlated with the changes in shooting standing performance. As strength levels declined, there was also a decline noted in the shooting standing score and vice versa. Serum cortisol concentrations increased throughout the entire training period and serum testosterone concentrations decreased when the loading was high. These results support earlier findings in the field, and one future consideration is to consider excluding the shooting prone test because shooting from a standing position seems to be more sensitive to fatigue and is thus perhaps the better measure of how fatigue affects shooting.

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