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JYVÄSKYLÄN YLIOPISTO

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ABSTRACT

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The present series of studies investigated changes in Finnish conscripts' body composition, aerobic fitness and muscle endurance profiles during the last three decades. A second aim was to examine the effects of added endurance (ET) or strength training (ST) on cardiovascular and neuromuscular performance as well as hormonal responses of conscripts during an 8-week basic training (BT) period when compared to the current standardized (NT) programme. The third aim was to study the effects of these three different training programmes on a novel 3K combat running performance test.

The present results showed that aerobic fitness and muscle endurance of 20 year old men in Finland has decreased and that body mass has increased over the last 15 years. Furthermore, the present study demonstrated that the current BT programme of the Finnish Defense Forces, including a high amount of endurance-based military training, led to significant improvements in maximal oxygen uptake, 3K loaded combat running time, and maximal strength of both upper and lower body extremities of conscripts. However, strength development and muscle hypertrophy in the ST group was not significantly higher than in the other groups. Significant increases observed in serum basal testosterone concentrations in all groups indicated that training frequency, volume and intensity were sufficient enough to create positive training responses but ST combined with BT led to increased serum basal cortisol concentrations. The BT programme positively influenced body composition by decreasing body fat and waist circumference in all groups.

The magnitude of training-specific gains from added endurance training and from added strength training were blunted by the demands of BT alone, as only minor differences existed between the three groups. The present study suggests that strength training is an essential part of the basic training programme, but it seems that in order to obtain more strength specific training responses, some decreases in the amount of the endurance-based military training are needed. Moreover, some individualization of specific ET and ST training programmes combined with military training may be required.

Keywords: Military, basic training, endurance, strength and fitness

Author's address Matti Santtila
Finnish Defence Forces
Defence Command
Personnel Division,
P.O. Box 919
FIN-00131 Helsinki
Finland

Supervisors Professor Keijo Häkkinen, Ph.D.
Department of Biology of Physical Activity
Neuromuscular Research Center
University of Jyväskylä, Jyväskylä
Finland

Professor Heikki Kyröläinen, Ph.D.
Department of Biology of Physical Activity
Neuromuscular Research Center
University of Jyväskylä, Jyväskylä
Finland

Reviewers Bradley C. Nindl, Ph.D.
Performance Physiology Team Leader
Military Performance Division, Natick, MA
The U.S. Army Research Institute of Environmental Medicine
USA

Professor Gordon J. Bell, Ph.D.
Director of the Sport and Health Assessment Centre
Faculty of Physical Education and Recreation
University of Alberta, Alberta
Canada

Opponent Colonel Karl Friedl, Ph.D.
Director of the U.S. Army Medical Research and Materiel Command's Telemedicine and Advanced Technology Research Center
Fort Detrick, MD
USA

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ORIGINAL PAPERS

This thesis is based on the following original research articles, which will be referred to by their Roman numerals.

I Santtila M, Kyröläinen H, Vasankari T, Tiainen S, Palvalin K, Häkkinen A, Häkkinen K (2006) Physical fitness profiles in young Finnish men during the years 1975–2004. Med Sci Sports Exerc. 38:1990–94.

II Santtila M, Häkkinen K, Karavirta L, Kyröläinen H (2008) Changes in cardiovascular performance during an 8-week military basic training period combined with added endurance or strength training. Mil Med. 173:1173-79.

III Santtila M, Kyröläinen H, Häkkinen K (2009) Changes in maximal and explosive strength, electromyography, and muscle thickness of lower and upper extremities induced by combined strength and endurance training in soldiers. J. Strength Cond. Res. 23:1300-1308.

IV Santtila M, Kyröläinen H, Häkkinen K (2009) Serum hormones in soldiers after basic training: Effect of added strength or endurance regimens. Aviat Space Environ Med. 80:615-620.

V Santtila M, Häkkinen K, Kraemer WJ, Kyröläinen H (2010) Effects of basic training on acute physiological responses to a combat loaded run test. Mil Med. (In press).

CONTENTS

1 INTRODUCTION

It is well known that aerobic capacity and muscle strength are important elements of fitness in the military environment, as well as in human daily activities. Good aerobic capacity and muscle strength are needed in society from professional soldiers attempting to optimize their peak performance to adolescents and elderly people carrying out their daily duties. Adequate aerobic and muscle fitness, regular physical activity, and proper health-related behaviours are essential for mental well-being, sufficient functional capacity and the prevention of overweight/obesity. All of these elements are also associated with a better quality of life (Blair and Church 2004).

Considerable discussion has been stimulated in society by the decline in the physical fitness of adolescents and the increased tendency to be overweight; however, very little reliable research-based evidence exists in this regard. It is well known that obesity in youth has increased during the last ten years in Western countries (Blair et al. 2004). Particularly the prevalence of obesity has increased across all age and social groups during the last twenty years (Kuczmarski et al. 1994, Blair and Church 2004, Weinstein et al. 2004). This phenomenon is a significant challenge for the military community and in the recruitment of capable soldiers. Modern military operations are physically demanding for both soldiers and their leaders despite technological developments. In addition to military skills, successful operations require particularly good physical and mental readiness.

Military occupational tasks, together with demanding working environments, often expose soldiers to multiple stressors. During sustained operations, these stress factors are very demanding on a soldier's physical and mental performance due to caloric deficit, sleep deprivation, continuous physical activity, and different kinds of disturbances in mood states (Nindl et al. 2007). Military activities also consist of several tasks like carrying or lifting heavy loads and materials, digging and shovelling actions, or demanding marches with extra loads of combat gear weighing 25-65 kg. Sometimes, these actions take place in very harsh environments or mountain conditions.

Therefore, in military operations and crisis management, high levels of both aerobic capacity and muscle strength are required.

Current military operations require soldiers to be on duty for long periods of time without rest, and also require soldiers to recover from the stress of combat more quickly (Nindl et al. 2007, Sharp et al. 2008). Soldiers should be able to cover a wider area and retain their capacity for action under demanding combat conditions during all seasons of the year and times of day or night (Tilander 1999). The pace of battle and the destructive force of modern weapon systems require rapid actions and reactions from regular soldiers and their leaders. Thus, one of the duties of commanding officers is to train her/his troops to withstand both the physical and mental pressures of the battlefield and, on occasion, to tolerate substantial losses (TRADOC 1995). Despite a considerable amount of recent technological advancements and increasing mechanization, a high level of physical fitness has remained an essential requirement of the modern soldier (Dyrstad et al. 2006). A high level of physical fitness is also an occupational requirement for soldiers (Sharp et al. 2008).

In Finland, all men perform compulsory military service, which is still a basic element of our national defence. In the Finnish Defence Forces, the purpose of physical training is to create a foundation for other aspects of military training, and to support the latter by providing instruction and training in the physical skills that are essential under combat conditions. In addition, every effort is made to inspire an interest in physical exercise and to instil permanent physical exercise habits in conscripts and soldiers with the hope that these habits will eventually transfer to the reservist and his/her children. A wide range of physical training develops motor skills, and at the same time develops endurance and/or muscle strength. Incidentally, this includes muscle stretching and relaxation in order to promote recovery after demanding exercises and to create opportunities for the optimal development of physical fitness.

The present research was designed to investigate the aerobic and muscle fitness profiles of Finnish conscripts (study I) as background information for the present study. Furthermore, the purpose was to examine hormonal responses and adaptations as well as conscripts' cardiovascular, neuromuscular and field running performance during an 8-week military training period combined with added endurance or strength training (study II-III).

2 REVIEW OF LITERATURE

2.1 Physical fitness and body characteristics of male recruits and conscripts

Compulsory military service has been replaced by professional armies in many countries during the last decades due to the higher demands and commitment required of soldiers and the armed forces in general. However, in countries with compulsory military service, it is not possible to select only the most physically and mentally well prepared males and females to perform their military service as it is in professional armies. Correspondingly, dramatic changes have been seen in the military environment, where recruits' or conscripts' physical and mental performance has decreased year by year. For example, in young Norwegian men, the maximal oxygen uptake of conscripts entering military service has decreased while obesity has increased during the years 1980-2002 (Dyrstad et al. 2005). This trend has also been observed in other Nordic Countries like Denmark and Sweden (Sörensen et al. 1997, Rasmussen et al. 1999). In previous studies, subjects have been representatives of a selected sample of the population, thus, results of these studies do not represent the whole population of a particular country or of a certain age group.

Leyk et al (2006) have reported that body weight has increased and physical fitness has decreased in non-obese young adults in Germany. The authors also found that more than 37% of the applicants for the German Bundeswehr (n=58000, aged 17-26 and BMI below 30 $kg \cdot m^{-2}$) failed their physical fitness tests. The failure rates have increased since 2001 and only 5.3% of applicants were able to run more than 2851 metres in the Cooper test. In contrast, in the U.S. Army, the physical fitness of recruits has not changed dramatically during the years 1978-1993 (Sharp et al. 2002). Sharp et al (2002) have reported that only body mass has increased significantly in U.S. Army recruits, while aerobic capacity, muscle strength and free fat mass have not changed. Later, Knapik et al (2006) reported that the maximal oxygen uptake of male recruits did not change during the years of 1975-1998, while slower times on 1-mile and 2-mile running tests indicate declines in aerobic performance during the years of 1987-2003. The authors also suggested that the apparent discrepancy between VO_2max and endurance running data may suggest that recruits are not as capable of applying their aerobic capacity to military tasks, possibly because of increased bodyweight, reduced running experience, lower motivation and/or environmental factors. Nevertheless, there is little scientific information available concerning the measured changes in physical fitness and physical activity of young people during the last decades.

The decline in physical fitness of young people entering or recruited for military service has made it more challenging for the armed forces to accomplish their task of training skilled troops to have a high performance capacity for deployment in peacekeeping and crisis management operations, or even for war. It seems that the current, more technical nature of warfare has not reduced the physical requirements of soldiers. In fact, there is no scientific evidence to suggest that soldiers at all levels of command and function might not need good physical and mental performance capacity in order to carry out their duties satisfactorily. Furthermore, the requirements placed on combat units and others apply to all branches of the armed forces.

It became evident in the Gulf War, for example, that the poorest third of the US infantry, the artillery gunners and support troops, were the weakest link in the initial offensive, as they failed to demonstrate the necessary stamina in the terrestrial phase of the warfare (David 1999). It was also suggested that the soldiers' physical performance capacity diminished rapidly during fighting and that there was insufficient time between engagements for recovery or additional physical training. The conclusion was reached that the physical performance capacity of troops should be of a high standard prior to deployment (David 1999, Nindl et al. 2007).

It is well-known that the decline in soldier's physical and mental performance during operational stress is rapid and unavoidable. Nindl et al (2007) have highlighted the importance of initial fitness level before military training and operations. The authors have further suggested that before military operations, optimization of training programs enhances physical performance, which logically counteracts some of the deleterious effects on physical performance during operations. The recent study of Sharp et al (2008) strongly supports these previous suggestions. The authors observed that a 9-month military operation in Afghanistan caused a significant decrease in U.S. Army soldiers' aerobic performance and upper body anaerobic power which is possibly due to the low training frequency during the operation and resulting detraining (Mujika and Padilla 2001). Physical performance capacity, including good muscle fitness is also an important factor in the prevention of stress fractures and other injuries in soldiers (Hoffman et al. 1999, Knapik et al. 2001). In addition, a high level of muscle strength is job requirement and essential for all soldiers.

2.2 Description of the military service and physical training of conscripts

Some 30,000 young people in Finland with a mean age of 20.3 years enter National Service each year, for a period of 6, 9 or 12 months. Nowadays, approximately 80 percent of each age class completes their military service. The first eight weeks of service are spent in basic training (BT), i.e. acquiring the fundamental knowledge and skills required for military service. In general, the main purpose of BT, lasting from 6 to 12 weeks (depending on the armed forces) is to prepare soldiers mentally and physically for the military environment and subsequent training. In addition, the aim is to support soldiers in their continuous learning process and to ensure a progressive improvement in their physical fitness over the entire duration of their military service. It is at this stage of training that the foundation is laid for participation in more demanding troop and combat training that occurs later, such as 8 weeks of special training and 9 weeks of unit training. In Finland, additional BT objectives include strengthening conscripts' national defence will, improving their military capabilities, and enhancing their physical fitness and motor skills.

The primary methods employed for improving the physical fitness of conscripts include: combat training, marching, sport-related physical training (SRPT) other physically demanding military training such as close-order drills. The aim of these different training methods is to develop the conscripts' physical fitness and exercise skills and to stimulate a positive attitude towards physical exercise. The goal is to achieve a level of physical performance that will ensure that upon transfer to the reserves, conscripts will be able to take on combat activities consistent with the requirements of their branch of the armed forces and area of training. Upon transfer to the reserves, conscripts should be able to carry-out the previously mentioned activities for an uninterrupted period of two weeks, and furthermore, they should be able to concentrate all of their strength on a sustained and decisive battle for 3-4 days and nights at a time.

Physical training accounts for almost half of the approximately 300 hours allotted to basic training, (i.e. 141 hours, or an average of about 17 hours a week), while SRPT takes up 52 hours, or about 17% of the BT time. The total time spent on physical training during the six months of military service is approximately 450 hours, which corresponds to the amount or training that many endurance athletes put in during a six-month period. Optimally planned and correctly implemented, this amount of training should easily enable a conscript to develop the endurance capacity required for military purposes. The total time of physical training within military service of rank and files is presented with details in Table 1.

TABLE 1 Physical training of rank-and-file soldiers during the 6-month military service (hours).

Training season	Combat	March	Close combat	Sport related physical training	General military training	Total
Basic	50	30	8	52	5	145
Special	60	30	8	60	5	163
Unit	80	0	9	50	2	141
Total	190	60	25	162	12	449

Physical training is implemented in a progressive manner, so that initially, the training methods used are largely those of SRPT. Conscripts should reach their maximum performance capacity during the unit training period at the end of their military service. Although the principal emphasis during combat training is on combat skills and techniques, combat training, together with marching, serves to improve endurance and strength performance. Since the risk of stress injuries is greatest during the first 2–6 weeks of BT (Jones and Knapik 1999, Rosendahl et al. 2003, Mattila et al. 2007), the physical load of training at this stage is relatively light and individualized as much as possible. In practice, training is performed in three groups based on prior volume of physical activity (three months before military service).

The role of SRPT during the period of special training is to support physical training by providing additional loading at times when other activities are physically less demanding and vice versa. At the troop training phase, sufficient physical loading is provided by the combat exercises and combat shooting camps, often lasting several days at a time, so that exercise training is devoted mainly to recovery and mental relaxation.

The physical training during BT consists mainly of endurance training performed at a low aerobic level for between one hour and several hours at a time, but physical training also includes interval-type exercises performed at, or slightly above, the anaerobic threshold for 5–30 minutes. Strength development is enhanced by muscle endurance training; however, no real strength training is included in the current BT programme. Nevertheless, some explosive power training such as jumping, sprinting and lifting routines are performed as a part of military training.

The energy load and estimated intensity levels of work and daily duties can be expressed by oxygen consumption (l/min, $ml \cdot kg^{-1} \cdot min^{-1}$), watts (W), joules (J), kilocalories (kcal) or metabolic equivalent (MET). For example, a MET is defined as the ratio of work metabolic rate to a standard resting metabolic rate of 1.0 (4.184 kJ) $\cdot kg^{-1} \cdot h^{-1}$ or as oxygen consumption of 3.5 $ml \cdot kg^{-1} \cdot min^{-1}$. MET values can vary between resting, a value of 1.0 (sleeping) to very high intensity work, a value of 18 METs (running at 10.9 mph) (Ainsworth et al. 2000). Pate et al (1995) have proposed the following method for classifying the MET intensity of physical activities (PA); light PA, < 3 METs; moderate PA, 3–6 METs; vigorous PA, > 6 METs).

Military training mostly induces a medium to heavy work load, where the medium level corresponds to work at the aerobic intensity of 25–40% of maximum with a pulse rate of 100–125 bpm, an energy expenditure of 5.0–7.4 kcal/min, an oxygen consumption in the range 15.3–22.9 ml $\cdot kg^{-1} \cdot min^{-1}$ and 3-4 METs (Grandjean 1989, Ainsworth et al. 2000, McArdle et al. 2001). Most activities referred to as daily work, walking (4–5 km/h), light military training and other military activities like handling of weapons and equipments belong in this category (Ainsworth et al. 2000).

Military training also consists of activities with a heavy work load, which corresponds to submaximal work at the aerobic intensity of 40-60% with a pulse rate of 125 – 150 bpm, an energy expenditure varying in the range 7.5–9.9 kcal/min, and an oxygen consumption of 23.0 – 30.6 ml $\cdot kg^{-1} \cdot min^{-1}$ or 5-6 METs (Grandjean 1989, Ainsworth et al. 2000, McArdle et al. 2001). The hardest work done in the context of walking (6 km/h) and construction work belong to this category, as do military marching in natural terrain, combat training and most SRPT (Ainsworth et al. 2000, Kyröläinen et al. 2008).

The physical loading involved in military training can momentarily also reach the very heavy level. This represents maximal work at the aerobic intensity of 60–100% with a pulse rate above 150 bpm, an energy expenditure of over 10 kcal/min, and an oxygen consumption in excess of 30.7 ml $\cdot kg^{-1} \cdot min^{-1}$ or METs over 7 (Grandjean 1989, Ainsworth et al. 2000, McArdle et al. 2001). This category includes demanding forestry work, other heavy manual and constructional work. Within military field training, this covers strenuous marches in cross-country terrain, active phases of prolonged combat exercises, and high-intensity SPRT (Ainsworth et al. 2000, Nindl et al. 2006, Kyröläinen et al. 2008).

Conscripts are often forced to carry extra loads during military training. For example, their combat dress and gear weighs, on average, some 25 kg and they also have to carry their personnel weapon and other equipments appropriate to their specific military function. Their ability to cope with the demanding environment on the battlefield and their resistance to stress injuries will therefore be improved greatly by high levels of endurance and strength. Consequently, strength training plays an important role in their physical training and conditioning alongside endurance.

2.3 Cardiovascular adaptations to typical endurance training

Endurance is one of the essential components of physical fitness in a soldier. Regular endurance training induces major adaptations in cardiorespiratory function and skeletal muscles. Therefore, the aim of endurance training is to improve the respiratory capacity of muscle fibres, lipid utilization and oxidative capacity of specific muscle groups. Therefore, long-term endurance training improves maximal oxygen uptake (VO_2max) by increasing aerobic enzyme activity in the muscles and by improving intramuscular glycogen stores. VO_2max is generally accepted as a measurement of cardiorespiratory endurance. Cardiorespiratory endurance is an important characteristic of physical fitness due to its high correlation with health and health risks (Blair et al. 1996, Wilder et al. 2006). For example, increased body fat mass and body fat percent are shown to be strong predictors of poor physical fitness (Mattila et al. 2007).

The major metabolic adaptations of the muscles to endurance exercise include slower utilization of muscle glycogen and blood glucose, greater reliance on fat oxidation, and less lactate production during exercise of a given intensity (Holloszy and Coyle 1984). Endurance training increases capillary density and mitochondrial size (Holloszy and Coyle 1984). As a consequence of the increase in mitochondria, exercise of the same intensity results in a disturbance in homeostasis that is smaller in trained than in untrained muscles (Holloszy and Coyle 1984). Endurance training has also been shown to increase the size and stroke volume of the heart (Saltin 1969). In addition, the arterial volume has been shown to be more than 30% greater in endurance athletes, most noticeably cyclists and cross-country skiers, than untrained subjects (Blomqvist and Saltin 1983). All of these adaptations have an important role in the increased ability to perform prolonged strenuous exercise (Holloszy and Coyle 1984).

For achieving improvements in physical performance, the body's homeostasis has to be disturbed. In this case, the initial performance level, or the number of repetitions of the exercise, its intensity and duration as well as the type of exercise must be taken into account (Rusko et al. 1986, McArdle et al. 2001, Åstrand et al. 2003). In terms of endurance exercises, specificity of training includes choice of the correct muscles and myocytes, energy production mechanisms, the distribution of training intensity between the systemic circulation and muscle tissues, movement velocity, force development and the exploitation of energy sources (Åstrand et al. 2003). Endurance training can be divided into interval, long-duration, or continuous training (McArdle et al. 2001). The adaptation to a certain type of endurance exercise takes 3–6 weeks, whereupon resting heart rate (HR) and HR at submaximal load decrease. In addition, muscular enzyme activity levels and lactic acid concentrations at a given load decrease due to increases in heart size and stroke volume, as well as some adaptations in other physiological functions. These adaptations are impaired if the training intensity, volume and/or duration is not progressively increased. The aim in endurance training is to reach a state in which muscular, functional and structural properties are all being equally utilized (Rusko et al. 1986, Åstrand 2000).

Endurance training can be divided into the basic, high intensity and maximal training. Basic endurance training, performed at a low intensity, develops the fat utilization capacity of muscles and increases their capillary blood vessel density. This latter effect, together with the increase in cardiac stroke volume, helps to improve the oxidative capacity of muscles. The duration of basic endurance training varies from one hour to several hours, and the intensity of long-duration training should be 60–80% of VO_2max (Rusko et al. 1986).

The next level, high intensity endurance training, is designed to develop respiratory and circulatory functions, the oxidative and glycolytic capacities of the muscles, and the elimination of lactic acid from the muscles. This can vary in intensity between the aerobic and anaerobic thresholds, and the duration of an individual exercise bout can depend on its nature and intensity. A long exercise bout performed at constant speed can last from 30 to 60 minutes. Interval-type exercise bouts consist of a number of shorter bursts performed at various HR levels, and their duration varies from few tenths of a second to a few minutes. The recovery time required between intervals will depend on the length of the training periods (Åstrand 2000, McArdle et al. 2001). The development of cardiovascular performance and particularly the improvement of VO_2max calls for maximal endurance training at an intensity above the anaerobic threshold. This training usually occurs as intervals of 3–10 min in duration performed at a constant speed and lasting for a total of 10–45 minutes (Holloszy and Coyle 1984, Åstrand et al. 2003).

Maximal oxygen uptake can be improved by means of a period of 2–3 months' exercise, when given a baseline level of 50–60 $ml \cdot kg^{-1} \cdot min^{-1}$ (Saltin 1969). Greater improvements can be achieved when the initial baseline level is lower than this, such as with untrained subjects. Experiments have shown, however, that maximal oxygen uptake in healthy young adults can be enhanced by almost 25% following a 10-week training period in which the subjects cycled or ran for 40 minutes a day six days per week (Hickson and Rosenkoetter 1981). Little research is available on oxygen uptake capacity in combat situations.

As previously mentioned, high level endurance capacity is a basic element of the capable soldier. Some reports have demonstrated a significant increase in soldiers' aerobic capacity, especially during the first 6-12 weeks of basic training (BT) (Patton et al. 1980, Marcinik et al. 1985, Gordon et al. 1986, Kraemer et al. 2004, Dyrstad et al. 2006). In contrast, some studies have found no changes or even a reduction in VO_2max, following BT (Daniels et al. 1979, Marcinik et al. 1985, Legg and Duggan 1996, Faff and Korneta 2000, Dyrstad et al. 2007). A high initial aerobic fitness level or an inadequate amount of high intensity aerobic training, have been the main reasons for the lack of improvement in VO_2max (Dyrstad et al. 2006). For example, Dyrstad et al (2006) have reported that soldiers with an initial VO_2max of over 54.9 $ml^{-1}kg^{-1}min^{-1}$ did not achieve additional benefits in terms of aerobic fitness during BT. They have also explained that poor improvement in soldiers' endurance performance is due to an inadequate amount of high-intensity endurance training during military service.

In another British investigation, the effects of three, five and eleven months of basic training on the aerobic capacity and muscle endurance of young men was studied. It was found that those subjects that initially had a high VO_2max showed no significant improvement in their VO_2max, whereas subjects with lower initial values showed significant improvements. Their development in VO_2max occurred quickly during the first three months, then slowed down or came to a halt between 3 and 5 months and advanced slightly once more between 5 and 11 months (Legg and Duggan 1996).

According to the general recommendations (Haskell et al. 2007) to improve physical fitness, promote and maintain health, all healthy adults require moderate-intensity endurance-based aerobic exercise for a minimum of 30 minutes, five days a week. Examples of this type of exercise include: vigorous walking and other activities that noticeably increase the heart rate. It is possible to achieve sufficient daily physical activity by performing vigorous-intensity aerobic exercises for at least 20 minutes on three days a week. Examples of these activities include, for example, jogging or other exercises which cause increased ventilation and a substantial increase in heart rate. These recommendations can also be fulfilled by combinations of moderate- and vigorous-intensity physical activity. Individuals who wish to further improve their physical fitness, reduce their risk for chronic diseases and disabilities or to prevent unhealthy weight gain may benefit from exceeding the minimum recommended amounts of physical activity due to the dose-response relation between physical activity and health.

2.4 Neuromuscular adaptations to strength training

Endurance-based military training and activities require a high level of aerobic capacity. In addition, neuromuscular performance has become more and more important in soldiers' daily activities. However, the neuromuscular adaptations to strength training are considerably different when compared to endurance training. Muscle strength has been defined as the maximum force generation capacity (Macaluso and De Vito 2004), in which the neural factors regulate muscle force generation. Muscle strength is specific to a particular muscle or muscle group and refers to the maximal force that the muscle or muscle group can generate. Increased levels of muscle activation and the consequent increase in muscular force are achieved by increases in the firing rate of each motor unit, changes in the pattern of motor unit activation and the recruitment of more motor units (Komi 1986, Häkkinen 1994, Kamen 2005). Rate of force production (RFD) is also an important factor of physical performance. Adaptations to prolonged strength training are mainly due to the combination of multiple factors such as mechanical stress, neuromotor control, metabolic demands, and endocrine activities (Kraemer and Ratamess 2005).

Depending on the type of muscle actions, strength can be divided into isometric, and dynamic (eccentric and concentric) components, while natural human locomotion is a combination of dynamic components (stretch-shortening cycle of muscle action). Dynamic strength can be assessed by measuring the movement of an individual's body against an external load. Based on the requirements for energy output, strength is generally divided into maximal strength, explosive strength (power) and muscular endurance. Muscles can utilize both glucose and free fatty acids as energy sources, and /or store these energy sources in the muscle, an important factor in maintaining energy balance in a body (McArdle et al. 2001). The ability of a muscle group to perform repeated contractions over a specific period of time that is sufficient to cause fatigue is termed muscular endurance (Wilder et al. 2006).

A key factor for successful strength training at any level of fitness or age is an appropriate program design (Kraemer and Ratamess 2005). It has been demonstrated in several strength-training studies that 2–3 training days per week is an effective initial frequency of training for untrained individuals (Kraemer and Ratamess 2005), whereas 1–2 days per week appears to be an effective training frequency for strength maintenance for those individuals who are already engaged in a resistance training program. Training frequency for the advanced trained individuals varies considerably. Most strength training studies have been short-term (6 to 24 weeks), and they have mostly used untrained individuals as subjects. In these studies, the majority of strength gains take place within the first 4–8 weeks (e.g. Hickson et al. 1994). During the initial weeks of strength training with high loads, neural adaptations are followed by muscle hypertrophy. These adaptations are associated with gains in maximal strength of the trained muscles (Komi 1986, Sale 1988, Häkkinen 1994). After several weeks of resistance training, the role of hypertrophic adaptations will progressively increase (Häkkinen 1994). Adaptation to strength training is due several crucial elements including mechanical stress, neuromotor control, metabolic demands, and endocrine activities (Kraemer and Ratamess 2005).

As previously mentioned, muscle strength gains during the initial phase of strength training are mainly due to neural adaptations, while muscle hypertrophy takes a more significant role in strength development over a prolonged strength training period (Moritani 1993, Häkkinen 1994). In addition, strength improvements of the untrained and trained individuals differ to a large extent. Moritani (1993) demonstrated that neural and hypertrophic adaptations, in association with strength development of untrained subjects, are faster and more pronounced than in well trained subjects, especially, in the beginning of the resistance training period. A review by Kraemer and Ratamess (2005) suggested that the muscular strength development capacity of untrained individuals might even be 3- 4-fold higher than that of trained individuals over periods ranging from 4 wk to 2 yr. The specific neural adaptations increase the activation of motor units, which is especially important for the development of explosive force (Häkkinen 1989, 1994). Most of the evidence for increased muscle activation after strength training has been demonstrated by electromyografic (EMG) measurements (Komi and Buskirk, 1970, Häkkinen & Komi 1983, Häkkinen et al. 1998c, 2003, Suetta et al. 2004). EMG is a method of recording and quantifying the electrical activity (muscle fibre action potential) produced by activated motor units. In a typical training study, EMG is recorded before and after training from selected agonist muscles during maximal voluntary contractions. Most commonly, EMG recordings are performed by utilizing surface electrodes, which are placed on the skin above the selected muscle.

Strength training has little effect on an individual's maximal oxygen uptake relative to endurance training, but has a distinct positive effect on the economy of human movement such as running (Johnston et al. 1997, Kyröläinen et al. 2000). Furthermore, strength training improves physical performance in activities with extra loads (carrying combat gear and / or amour belt) (Dudley and Djamil 1985). Kraemer and Ratamess (2005) have suggested, that strength training for normal people, who are trying to improve their general physical fitness, health status and well-being, involves exercises like muscle strength, local muscular endurance and hypertrophy. Correspondingly, competitive training and training for professional soldiers involves strength training to maximize muscle hypertrophy, strength, power, and/or local muscular endurance. Strength training programmes usually consist of several components such as muscle actions, resistance, volume (total number of sets and repetitions), exercise type and workout structure (e.g., the number of muscle groups trained), the sequence of exercise performance, rest intervals between sets, repetition velocity, and training frequency (Kraemer and Ratamess 2005). The alternation of these variables will have an effect on the training response.

It has been shown that strength training in soldiers induces positive changes in body composition and power production of the lower body extremities after a 12-week training period (Kraemer et al. 2004). Strength training also improved the occupational task performances in the duties that are involved in upper-body musculature due to the activation of type II motor units, which are known to be activated even during exercises performed with light loads if high action velocity is used (Kraemer et al. 2001). Some other reports have also demonstrated significant increases in the soldiers' muscle strength and material handling ability during a 6-12 week military training period (Gordon et al. 1986, Legg and Duggan 1996, Faff et al. 2000, Williams et al. 2002). Some reports have, however, made contradictory findings, where no or limited improvements in strength were found (Marcinik et al. 1985, Dyrstad et al. 2006, Kraemer et al. 2004, Nindl et al. 2007). Kraemer et al (2004) have suggested that one reason for the lack of improvements in muscle strength might be the consequence of an interference effect resulting from combined endurance and strength training which seems, quite often, to be the nature of military training.

As previously described, not only is a good level of physical fitness including adequate muscle strength and muscle endurance is essential for soldiers, but also for the prevention of injuries. Several studies have demonstrated that low levels of aerobic performance, muscle fitness and strength as well as flexibility are the main risk factors for the injuries during the military service (Jones et al. 1993, Knapik et al. 1993, Jones and Knapik 1999, Hoffman et al. 1999, Knapik et al. 2001, Rosendal et al. 2003, Mattila et al. 2008). In addition, previous injury history, complaints or injuries related to the lower back and knees, poor mental health, high amounts of running or running mileage during BT, sedentary lifestyle before the military service, overweight and tobacco use have been shown to be significant risk factors for injuries (Jones and Knapik 1999, Knapik et al. 2001, Mattila et al. 2008, Larsson et al. 2009). These previously mentioned risk factors can also be used to predict premature discharge from the military service and limited duty days (e.g. Jones and Knapik 1999, Mattila et al. 2008, Larsson et al. 2009).

2.5 Effects of combined endurance and strength training on cardiovascular and neuromuscular performance

In order to simultaneously improve aerobic fitness and muscle strength, specific attention must be paid to create the optimal combination of endurance and strength training. Hickson (1980) originally reported that concurrent strength and endurance training can interfere with strength development of the trained muscles. The author showed that a high volume of concurrent endurance and strength training such as three plus three times a week did not interfere with strength gains during the first 3-4 weeks of training. However, strength development stabilized after 5-6 weeks of training followed by decreases in strength levels during the last 7-10 training weeks. The restricted strength gains under high volume concurrent training conditions over a prolonged period of time may be due to a limited change observed in skeletal muscle cross-sectional area and/or a reduced hypertrophy of individual muscle fibres (Kraemer et al. 1995). It has also been explained that fatigue induced by endurance training may hinder the ability to generate force during subsequent resistance training, which includes factors such as motor recruitment patterns, endocrine responses, and program design (Kowal et al. 1978).

Häkkinen et al (2003) have suggested, that when endurance and strength training are combined, it is important to take into consideration that even a low frequency of training, can lead to some interference in explosive strength development due to the limitations of rapid voluntary neural activation of the trained muscles. The reason for this lies in the increase in catabolic hormones that combined training induces incompatible compositions and rhythms of the two types of training (Bell et al. 2000, Häkkinen et al. 2003). At the molecular level, there also seems to be an explanation for this interference effect of endurance training on strength development during concurrent training. Nader (2006) has suggested that different forms of exercise induce antagonistic intracellular signalling mechanisms that, in turn, could have a negative impact on the adaptive response of muscles.

Although combined endurance and strength training has been shown to interfere with the strength development of trained muscles (Hickson 1980, Dudley and Djamil 1985), the research results available have also demonstrated that a short period of 3–6 weeks of combined training will lead to adaptations in terms of both endurance and strength (Hickson 1980, Bell et al. 1991). However, combined training with a high volume/frequency more than 7 weeks will lead to interference in strength development or even to a decreased level of strength (Hickson 1980, Dudley and Djamil 1985, Bell et al. 1991, Kraemer et al. 1995). Long-term combined endurance and strength training will also blunt the development of explosive strength due to the limitations of rapid voluntary neural activation of the trained muscles (Häkkinen et al. 2003).

Little scientific information is available on the effects of endurance and strength training on soldiers' physical performance. In a study by Williams et al (1999) the authors evaluated a typical 11-week basic training course in the British Army that consisted of various military loading and marching tasks but no formalized specific strength training program. From this study, they stated "...basic training in the British Army produces some favourable adaptations in recruits, especially in terms of aerobic fitness. However, the poor development of strength and material handling ability during training fails to improve the ability of soldiers to perform simulated military tasks, and it does little to reduce future injury risk while performing these tasks." Thus, it was apparent that more specialized training programs that would specifically target the development of strength were needed within the basic training course. To test their hypothesis that a modified basic training course with a specific strength training program would be more effective in improving military task performances, Williams et al (2002) conducted a follow-up study to investigate whether such a program could enhance the soldier's material-handling ability among other aspects of physical fitness. The authors found that a modified 11-week basic training course including a focused strength training program and the elimination of other extraneous exercise tasks could result in improved military task performances that were greater than the improvements observed following the normal basic training program.

A British Army report has demonstrated an improvement of 2.2% in maximal oxygen uptake tested by indirect bicycle ergometer in female soldiers, 15.9% increase in their hand grip strength, 10.1% increase in their lower body maximal strength and 2.4% increase their in fat-free muscle mass (FFM), with a corresponding reduction in their percentage of body fat (Brock and Legg 1997) during a 6-week basic training programme. It has been demonstrated that combined strength and endurance training induced improvements in aerobic capacity and upper body strength levels during an 8-week training period (Hennessey and Watson 1994). Nevertheless, it has been demonstrated that a high amount of military training interferes with muscle strength development and explosive power (Nindl et al. 2007). In addition, Kraemer et al (2004) have suggested that a high degree of specificity of the endurance or strength training is evident, when these two training regimens have been implemented concurrently.

2.6 Operational field performance

The predictive field test models related to battlefield physical performance and requirements may be beneficial when preparing for demanding operations, sometimes in harsh environments. Nevertheless, limited information is available about reliable military field performance tests. Loaded running and marching has typically been used as one of the military tasks together with digging or shovelling activities and carrying different kinds of loads or materials (Sharp et al. 1998). The loaded running and marching tests are widely used and valid performance tests. There are also typical task-related military field tests, by which soldiers' endurance and strength capacity can concurrently be evaluated (Kraemer et al. 2004).

In addition to the above-mentioned field tests, Nindl et al (2007) have suggested that vertical jump height can predict operational capabilities in situations with limited testing resources including equipment, time or environmental conditions. The data available support its utilization as an effective military field test. Using this method of testing, Nindl et al (2007) have also found that lower-body power output declined linearly with significant losses in lean body mass. Harman et al (2008) later supported these findings. In addition, they have found that greater body mass was positively associated with better casualty recovery performance.

In the study by Sharp et al (2008), the authors examined a wide array of tests including body composition measurements, lifting strength measured by an incremental lifting machine, lower and upper body explosive power measurements (vertical jump, medicine ball put) and aerobic capacity measurements. Yet only two tests demonstrated a detraining effect indicating that aerobic capacity and a novel upper body power skill test were the only abilities not maintained by typical unit physical training and combat operations.

One field test that taxes both the aerobic and strength capabilities of a soldier is the loaded running or marching tests (Kraemer et al. 2004, Nindl et al. 2007). Usually load tests reflect heavier demands and lighter combat loaded running tests have not been used to evaluate physical training programs in the military. Such tests would reflect some of the operational demands in combat situations. Some studies investigating the changes in male soldiers' aerobic performance, muscle strength or body composition during the military service is presented in Table 2.

TABLE 2 Studies investigating the changes in male soldiers' aerobic performance, muscle strength or body composition during the military service.

Study	Study Design	Main findings	Other findings
Vogel et al. 1978	3-month recruit training	Estimated VO_2max increased by 8%.	Body fat decreased by 8.6% without a change in body weight. Lean body mass increased by 2.0%.
Daniels et al. 1979	6-week military training	Females increased VO_2max by 7.9%. Males did not increase their VO_2max (59.4 vs. 60.6 $ml \cdot kg^{-1} \cdot min^{-1}$). 1-mile run time decreased in males by 11.2% and in females by 14.3%.	Both groups decreased HRmax and body fat percent. The initial difference in aerobic power between males and females decreased from 22% to 18%.
Patton et al. 1980	7-week military basic training.	Males increased VO_2max by 3.7% and females by 10.5% with training.	Body fat percent decreased in males by 11% and in females by 7.1%, while lean body mass increased in males by 2.6% and in females by 6.1%. Total body weight in females increased by 3.5% while in males it remained unaltered.
Daniels et al. 1982	Two years of military training. Experiment consisted of five separated evaluations.	VO_2max (1/min) increased in both sexes, while VO_2max ($ml \cdot kg^{-1} \cdot min^{-1}$) did not change in males during the study. VO_2max in females increased significantly after the initial 6 weeks of training (44.2 to 48.8 $ml \cdot kg^{-1} \cdot min^{-1}$). It remained the same through the second summer of training. By the end of second year it dropped to 45.9 $ml \cdot kg^{-1} \cdot min^{-1}$. Maximal isometric strength was 30-40% higher in males than in females. During the last year of training, arm and shoulder strength increased 10.2% in males, but unchanged in females.	Lean body mass and body weight increased significantly in both groups. Percent body fat was significantly reduced only after the first summer of training and then returned to the initial values.

Marcinik et al. 1985	8-week Navy standard recruit basic training and augmented training.	Participation in the standard BT program did not significantly alter the overall fitness level of the average recruit, while participation in the augmented training program provided superior stamina (by 13.6%) but not muscular strength gains.	
Gordon et al. 1986	South African Defence Force - one year military service	With the exception of elbow extensors, muscular strength increased (by 17%), fitness levels of the average and above-average recruits did not increase by the basic training.	VO_2max improved during the first 8-weeks of training by 8%, but thereafter it decreased to the initial levels.
Legg and Duggan 1996	British Army 3, 5 or 11 months of basic training	Adult Artillery Recruits – after BT body weight increased by 2.1% and VO_2max by 3.6% but mixed responses were observed for muscular strength, endurance and fatigue. Junior Infantry Soldier Recruits – no change in body weight but VO_2max decreased by 2.4% – isometric muscle strength increased significantly Junior Infantry Leader Recruits – body weight increased by 4.9% and VO_2max by 3.0% – isometric muscle strength increased significantly.	3 months of BT for Adult Artillery Recruits was sufficient in improving their aerobic fitness but not in improving muscle strength and endurance. BT for Junior Infantry Soldier Recruits over 5 months was effective in increasing muscle strength but not in improving aerobic fitness possibly due to their higher initial fitness level. BT over 11 months for Junior Infantry Leader recruits was effective in increasing body weight, aerobic fitness and muscle strength.
Williams et al. 1999	Normal British Army 11-week basic training	Repetitive lifting and carrying of a 22 kg load improved by 29.5% and 3.2 km loaded march performance with 25 kg by 15.7%, but march performance with a 15 kg load did not improve. VO_2max improved by 6.1%. No differences between the genders.	Fat-free mass increased by 1.5%, but body fat percent reduced by 2.7% and body mass by 1.7%. Females lost more body mass than males.

Faff et al. 2000	Paratroopers 18-month military training, measured at 3, 12 and 18 months of service	Soldiers improved their anaerobic power by 5.9%, anaerobic capacity by 9.7%), muscular endurance and explosive power by 32-78%, endurance by 12.4%, agility by 13.7%, speed by 11%, and static strength by 4%. No changes in aerobic fitness.	Military training produced increases in body weight by 4% and lean body mass by 5.7%, but a decrease in body fat from 15% to 13.1%.
Trank et al. 2001	5-month booth camp	Recruits who began training in Poor-Fair condition improved the most (15.6%) with an average decrease in 1.5 mile run time, the Good group improved by 7.3%, and the Excellent-Superior group improved by 2.9%.	The aerobic fitness improvements were directly related to baseline fitness level but not to running mileage or high-intensity running training during boot camp training.
Faff et al. 2002	3-month military training	Subjects with the lowest initial fitness level improved most their VO_2max (39.0 vs. 44.1 $ml \cdot kg^{-1} \cdot min^{-1}$) and anaerobic power (8.0 vs. 8.4 $W \cdot kg^{-1}$) values, while subjects with the highest initial fitness level decreased their values. A total subject group did not improve their values.	Body mass and body fat percent did not change, while lean body mass increased significantly. Body composition changes were most favourable for subjects with the lower initial fitness level.
Williams et al. 2002	Normal British Army 11-week basic training with modified physical training, which consisted of added strength training and a higher proportion of endurance and material handling training compared to normal British Army basic training (Williams et al. 1999)	Significantly greater improvements were observed in the modified training compared with the normal training – maximal box lift by 12.4 vs. 1.7% – 3.2 km loaded march performance by 8.9 vs. 3.6% – VO_2max by 9.3 vs. 4.1% dynamic lift by 15.5 vs. 0.2% – estimated fat-free mass by 4.2 vs. 1.5%.	The improvements in material-handling ability and other aspects of physical fitness during basic training can be enhanced by using a physical training programme that includes a carefully designed resistance training element.
Kraemer et al. 2004	12-week, 4 days per week, endurance training (ET), resistance training (RT), upper body resistance training + endurance training (UB+ET) or combined (ET+RT)	All groups improved push-ups (18-43%), RT + ET group did not improve sit-ups, the groups that included ET improved 2-mile unload run time, only RT+RT and UB+ET improved loaded 2-mile run time, leg power increased for the groups that included RT exercises.	All groups performing ET decreased body fat%, all groups performing RT increased body fat free mass. A high degree of specificity when combined training regimens are implemented.

Williams et al. 2004	10-week army basic military training including circuit or resistance training programmes	Both groups improved their loaded march performance divided into significantly different subgroups of 'good' and 'poor' responders by 20% and 10%, respectively.	Stronger subjects with lower endurance responded better to circuit training, while resistance training showed the opposite effect.
Dyrstad et al. 2006	Normal military basic training 10 weeks and 10-month after the entry	VO_2max increased by 5% for the subjects with the lowest initial level, no changes with medium level, the subjects with the highest initial level tended to decrease.	Significant increases in push-ups, sit-ups and 3-km running test. No change in chin-ups. No changes in body mass during the first 10 weeks of training, thereafter body mass increased.
Nindl et al. 2007	8-week intensive U.S. Army Ranger training	After the training course decreased were observed in vertical jump height by 16%, explosive power output by 21%, maximal lifting strength by 20%.	Significant decreases were recorded in body mass by 13%, fat-free mass by 6%, and fat mass by 50%.
Knapik et al. 2009	U.S. Army physical readiness training (PRT)	Results of the Army Physical Fitness Test were similar or higher in soldiers with PRT programs. In an 8-week laboratory study comparing PRT with a weightlifting/running program, both programs improved militarily relevant task performances like e.g. 3.2-km walk/run with 32-kg load, 400-m run with 18-kg load, or 80-kg casualty drag, obstacle run performances.	In three military field tests, the overall adjusted risk of injury was 1.5–1.8 times higher in soldiers performing traditional military BT programs compared to PRT program.

2.7 Effects of strength and endurance training on serum hormonal concentrations

Strenuous strength and endurance training has been shown to result in short and long-term alterations of the endocrine system (Bunt 1986, Galbo 1986, Viru 1992, Kraemer et al. 1995). Endocrine factors have significant regulatory effects on cardiovascular, neuromuscular and metabolic functions during endurance and strength training and associated adaptations to training stimulus. Adaptations in the neuroendocrine system have been related to force production, muscle hypertrophy and/or improved aerobic fitness (e.g. Galbo

1981, Häkkinen 1994, Kraemer et al. 1995). When strenuous physical training is carried out for prolonged periods with insufficient recovery between training sessions, the soldier, athlete, or normal trainer may become overtrained (Mujika et al. 1996). Strength and endurance training alter the balance of anabolic and catabolic hormones may reduce muscle hypertrophy, strength development and aerobic fitness. Although it may be an oversimplification, testosterone and cortisol have been used as markers for muscle anabolism and catabolism (Häkkinen at al. 1985, Kraemer and Ratamess 2005).

2.7.1 Acute responses

The magnitude of the acute exercise induced testosterone (TES) response is related to the age of the subject, the rest periods between exercises, the total work load, and the number of muscles activated (Kraemer et al. 1990, Häkkinen & Pakarinen 1993, 1995). Free testosterone affects the cells directly, promoting protein synthesis and muscular hypertrophy (Tenover 1994). It has been shown in several studies that strength training induces acute increases in total serum testosterone (e.g. Häkkinen and Pakarinen 1993, 1995, Kraemer and Ratamess 2005). Although several studies have not shown any chronic changes in serum basal testosterone (TES) concentrations (Kraemer and Ratamess 2005), strength training may influence acute TES responses so that optimal training volume and intensity may also cause increases in basal TES concentrations (Kraemer & Ratamess 2005), even in strength athletes (Häkkinen et al. 1988d).

Häkkinen and Pakarinen (1993, 1995) have found increases in acute serum growth hormone (GH) responses in young men after heavy dynamic resistance training. The increases of GH responses were in relation to the overall amount of the training load and type of protocol. These findings were supported by the earlier findings of e.g. Kraemer et al (1987). In addition, TES and GH are shown to be sensitive, in particular the stress of strength training is known to effect tissues in a variety of ways, including the stimulation of protein synthesis (Kraemer et al. 1990). Shorter periods of recovery between sets may increase GH and TES concentrations. Multiple-set of protocols have been demonstrated to increase GH and TES levels to a greater extent than single-set protocols (Gotshalk et al. 1997).

Endurance exercises have been shown to cause acute increases in serum TES, GH, IGF-1 and cortisol (COR) (Kraemer et al. 1995) concentrations, especially after brief and intensive exercises (Galbo 1981). However, endurance exercise of a prolonged duration (>2 h) can lead to acute decreases in TES (Kujala et al. 1990). With endurance training, no changes or even slight decreases have been observed in serum basal TES, GH, IGF-1 and COR (Duclos et al. 1997, Kraemer et al. 2005). Nevertheless, the endurance part of concurrent endurance and strength training could induce a more catabolic response, and therefore, may interfere with strength development. Interestingly, concurrent endurance and strength training has not been shown to reduce TES levels, but a systematic increase has been observed in serum COR (Kraemer et al. 1995).

Military training consists of several challenges including energy deficit (ED), sleep deprivation, heavy physical loading and different kinds of disturbances in mood states (Nindl et al. 2002), which disrupt body homeostasis indicated by hormonal responses.

2.7.2 Chronic changes

The majority of published reports have demonstrated that basal levels of serum hormones may not change during typical prolonged endurance or strength training (e.g. Häkkinen 1989, Kraemer and Ratamess 2005). However, Kraemer et al. (1999) have found that heavy strength training for 10 weeks significantly increased resting serum free TES concentration. In addition, Falkel et al (1994) have observed an increase in the resting levels of serum TES and a decrease in cortisol (COR) after 6 weeks of heavy resistance training in men.

The TES/COR ratio has been used to indicate the balance in anabolism or catabolism of the body (Häkkinen et al. 1985, Kuoppasalmi and Adlercrutz 1985). It has also been shown that 24 weeks of gradually intensifying strength exercises increases maximal strength development and serum testosterone concentrations, especially in the early stages (Häkkinen et al. 1985). Optimal training volume and intensity over a prolonged training period may lead to increases in basal TES concentrations even in strength athletes (Häkkinen et al. 1988d).

A military exercise, lasting for several days with a high level of stress, energy deficit and sleep deprivation, has been found to reduce testosterone concentrations by 30–90% (e.g. Opstad 1991, Gomes-Merino et al. 2003, Kyröläinen et al. 2008, Nindl et al. 2007). Furthermore, basal testosterone levels have been shown to decrease by 17% resulting from an intensive two weeks of endurance training in athletes (Griffith et al. 1990). In addition, several years of endurance training has been found to lead to lowered basal testosterone levels both in sedentary men and in competitive athletes (Wheeler et al. 1984, Hackney et al. 1988, Viru et al. 1992). On the other hand, in young male conscripts six months of strenuous physical activity increased basal testosterone levels relating to their maximal oxygen uptake (Remes et al. 1979).

Cortisol concentrations increase as a general reaction to stress or high-intensity exercise and in response to metabolic effects in the body (Koziris et al. 2000). The response is dependent on the form of exercise and its duration and intensity (Kraemer et al. 1989, Fry et al. 1993, Hackney et al. 1999). Measurements of the effects of various forms of exercise (interval, endurance and a combination of both) on the hormonal reactions of subjects over a period of ten weeks showed that the interval and combined exercises led to a significant increase in resting cortisol levels, while endurance exercises had only a minor effect. Kraemer et al (1989) have further shown that anaerobic exercises have a different effect on cortisol levels than aerobic ones. On the other hand, long-term physical stress, together with shortages of food and sleep increase soldiers’ cortisol levels considerably (Opstad 1994). Resting cortisol levels may well reflect the amount of exercise performed and the physical load involved

(Banfi et al. 1993), just as testosterone may be a good indicator of the overall loading imposed in strength exercises (Häkkinen et al. 1988a).

Nindl et al (2007) have suggested that 8 weeks of intensive military training increases circulating COR and declines TES and insulin-like growth factor concentrations. These changes were associated with losses in fat and fat-free mass. Their findings further suggested that with severe weight loss, serum COR and IGF-1 were better biomarkers of tissue loss than serum testosterone. Furthermore, it has been shown that an 8-week ranger course causes ED of 1000 kcal/day, which was clearly associated with decreases in thyroid hormones T3 and T4 (Friedl et al. 2000, Nindl et al. 2007). After the ranger course, a training period combined with higher energy intake (EI) caused a rapid restoration in serum T3 and TES (Nindl et al. 2007). The studies of Opstad et al (1991, 1992, 1994) support these findings. The primary action of thyroid hormones has been suggested to be to increase the muscle cell metabolic functions by stimulation of protein synthesis and carbohydrate metabolism. In addition, it may also induce indirectly lipolysis (Galbo 1981).

3 PURPOSE OF THE STUDY

The present series of studies investigated the changes in the conscripts' body composition, aerobic fitness and muscle endurance profiles over the last three decades. Furthermore, the aim of the present study was to examine the effects of added endurance or strength training on cardiovascular and neuromuscular performance of conscripts during an 8-weeks basic training (BT) period when compared to the current standardized programme.

The more detailed aims and hypothesis of the present studies were as follows:

1) To investigate the physical fitness profiles consisting of aerobic performance from 1975-2004, muscle fitness characteristics from 1982-2003, and anthropometric characteristics from 1993-2004 among Finnish male conscripts at the age of 20 years. The primary hypothesis of study I was that body weight of the conscripts has increased and at the same time endurance performance and muscle fitness characteristics have decreased throughout the study period. (Original paper I)

2) To examine changes in cardiovascular performance during an 8-week basic training (BT) period combined with added endurance or strength training. In addition, we examined whether it was possible to achieve extra benefits for the conscript's aerobic capacity by increasing the proportions of the endurance training. (Original paper II)

3) To investigate to what an extent an 8-week endurance based military training period interferes with muscle strength development in the conscripts compared to that caused by sport related physical training (SRPT) with added endurance or strength training. In addition, we wanted to study the effect of these three training modes not only on maximal isometric force production but also on maximal rate of force development (RFD), electromyography (EMG) and muscle thickness of the lower and upper extremities. (Original paper III)

4) To investigate changes in serum hormone concentrations of testosterone, cortisol, growth hormone and SHBG during an 8-week basic training with added strength (ST) or endurance (ET) training. Secondly, to study whether basal serum concentrations and their possible changes are related to changes in endurance and strength performance. (Original paper IV)

5) To investigate the effects of three different 8-week basic training courses: normal basic training (NT); basic training with added strength training (ST), or basic training with added endurance training (ET) on a novel 3K combat run test. A secondary purpose was to examine acute changes in neuromuscular force production capabilities and hormonal responses to 3K combat run test before and after the basic training period. (Original paper V).

4 MATERIAL AND METHODS

4.1 Subjects in studies I, II, and III

The data of study I is based on the fitness test results of 387 088 young healthy men (mean age of 19.9 yr.) for endurance performance, of 280 285 for muscle fitness characteristics, and of 324 911 for body anthropometric data. This data has annually been collected from several garrisons all over Finland. Thereafter, weighted means, normalized by the number of subjects in each garrison, have been collected and archived in the Training Division of Defence Staff. The running test data (n = 387 088) used for the measurement of aerobic fitness has been collected from 1975 until 2004. The sampling size varies from 5 799 to 27 142 during the years of 1975-1997 and from 16 168 to 26 761 during the years of 1998-2004. Muscle endurance data (n= 280 285) has been collected from 1982-2004, and its sampling size varies from 4515 to 26 771. The anthropometric data (n= 324 911) was collected since 1993, and the range of its sampling size varies between 20 689 and 30 659. The subjects gave written informed consent to participate in military service including the present tests after a physical examination by medical doctors. All of the subjects were fully informed of the procedures and possible risks of the experiment.

In studies II-III the total sample size was 72 male conscripts who were divided into an added endurance training (ET; n=24), added strength training (ST; n=24) and standardized basic training (NT; n=24) groups. The subjects were randomly selected for the study in the beginning of their military service. They were matched by their body mass, height and physical activity level. There were nine drop outs (ET 4, ST 3, and NT 2 persons) due to a premature discharge from the military service for mental reasons (2), sick leaves of over 14 days (2, no injuries), missing information from training diaries (2), failed measurements (2) or a change in the garrison (1). The mean age of the subjects was 19.2±0.9 years, mean height 1.79±0.06 m, initial body mass 73.8± 12.4 kg, and body mass index 23.0±3.8. The subjects voluntarily participated in the study after passing the medical examination. They were carefully informed about the design of the study with special information on possible risks and discomforts that might occur. Subsequently, they signed an informed consent prior to the experiment. This study was conducted according to the declaration of Helsinki 1975 and was approved by the Ethical Committee of the Central Finland Health Care District and the University of Jyväskylä, Finland.

4.2 Experimental design

The present thesis consisted of altogether three separate studies. Study I described the physical fitness profiles of the Finnish male conscripts at the age of 20 years during the years of 1974-2004 (original paper I) as background information for the experimental training studies. Study II examined the effects of added endurance or strength training on cardiovascular and neuromuscular performance of conscripts including possible changes in serum hormonal concentrations during an 8-weeks basic training (BT) period compared to the current standardized programme (original papers II, III and IV). Study III examined changes in conscripts' 3K field running performance following the previously mention training programmes (original paper V).

4.2.1 Study I

The aerobic fitness and muscle endurance tests of study I had been arranged mainly during the first two weeks of military service in different garrisons all over Finland. The data was collected by local fitness officers educated according to the standards determined by the Training Division of the Defence Staff.

4.2.2 Study II-III

The duration of the present BT period (studies II-III) was 8 weeks including a total of 300 hours military training. The standard BT programme for all groups consisted of combat, marching and shooting training, material handling, general military education, skill training and sport related physical training. During marching and combat training, the subjects carried a combat gear with a load of 15-25 kg. BT included field exercises lasting from 4 hours to up to 3 days for a total of 1-2 weeks. Garrison training involved theoretical education, material handling, shooting and general military education such as close order drills. The military training of the BT standard programme was mainly performed on the aerobic level. The overall amount of the sport related physical training (SRPT) was planned to be 50 hours for the BT. In this report SRPT consisted of running, nordic walking, walking, cycling, strength training, ball games, orienteering and other sport activities.

The SRPT programmes during BT for each group differed with regard to specific training sessions (Table 3). The ET group trained according to the BT standard programme. The SRPT programme of ET consisted of a higher proportion of endurance training, which included nordic walking, walking, running, cycling and some other endurance exercises. The ET group had three endurance sessions a week with the duration of 60 to 90 minutes. The training intensity was mainly aerobic (50-70% of maximal heart rate) but every third exercise session included intensity that exceeded the anaerobic threshold.

TABLE 3 The design of the training protocol of the study (II-III).

	Endurance training group (ET)	Strength training group (ST)	Normal training group (NT)
Basic training (BT) programme Total hours for all groups	300 hours	300 hours	300 hours
Military related physical training such as combat training and marching	100 hours	100 hours	100 hours
Sport related physical training such as running, nordic walking, walking, cycling, strength training, ball games, orienteering and other sport activities	51 hours **Higher proportion of endurance training (ET)** - 3 exercises a week - duration 60 to 90 minutes - intensity 50-70% max HR - nordic walking, orienteering, running, cycling and other endurance exercises	44 hours **Higher proportion of strength training (ST)** - 3 exercises a week - duration 60 to 90 minutes **- week 1 to 3:** loads 30-50% or 60–70 % of 1 RM/ 2-3 sets/10-15 or 20-40 reps **- week 4 to 5:** loads 60-80% of 1 RM/2-4 sets/6-10 reps **- weeks 6 to 8** loads 80-100% of 1 RM/5-7 sets/1-6 reps	33 hours **According to the standard BT programme (NT)** - 2-3 exercises a week - duration 60 to 90 minutes - orienteering, ballgames, circuit training and obstacle running
Other military training such as shooting, material handling, skill training, general military education and theoretical education	the rest of hours	the rest of hours	the rest of hours

The ST group trained also according to the BT standard programme. The SRPT programme of ST contained a special strength training programme. The ST group had three strength training sessions a week with the duration of 60 to 90 minutes. A whole body linear periodized strength training program consisted of gym and circuit training and each training session always included 2 exercises for the leg extensor muscles. During the first three weeks, the subjects trained with the loads of 30-50% or 60–70 % of 1 RM for 2-3 sets and 10-15 or 20-40 repetitions (muscle endurance), during weeks 4 and 5 with the loads of 60-80% of 1 RM for 2-4 sets and 6-10 repetitions (hypertrophy cycle), and finally during weeks 6 to 8 with the loads of 80-100% for 5-7 sets and 1-6 repetitions (maximal strength/power cycle). Additionally, explosive strength training exercises were performed twice during the last two training weeks. Strength exercises consisted of exercises such as bench press, leg press, leg extension, lunges, leg curls, squats, curls, pushdowns, front press, lateral press, push-ups, chin-ups, dips, pulldowns, seated rows, sit-ups, back extension and side bends.

The NT group served as a control group and trained according to the BT standard programme (Training Division 2004). The SRPT programme was performed in accordance with the standard BT programme, which consisted endurance type of activities such as orienteering, ballgames, circuit training and other exercises such as running of obstacle courses. The subjects (studies II-III) were tested on two different occasions using identical protocols. The initial endurance, strength and 3K field running tests, together with body composition and hormonal measurements, were performed during the first BT week and the second tests were performed during the ninth service week, after the 8-week BT season.

4.3 Measurements and analysis

4.3.1 Body height and mass

In study I, the body height and mass of conscripts was measured during the physical examination by medical personnel at the beginning of military service. Body mass (BM) was measured using a commercial scale to the accuracy of 100g wearing only shorts. Body height was recorded by tape measure in a standing position to the accuracy of 5 mm without shoes.

In study II, body mass was measured using a bioimpedance device (InBody 720, Biospace, Seoul, South-Korea), and body height was measured by a commercial scale. Thereafter, the body mass index (BMI) was calculated. BMI was used as a simple means of classifying sedentary individuals according to their body fat content. BMI could overestimate the body fat content in subjects with high fat free body mass (FFM) (Fogelholm et al. 2006a). As a rough guideline for adults, a BMI of less than 20 implies underweight, a BMI of over

25 is overweight, a BMI of over 30 is considered to be obese. During the BM measurements the subjects wore short underwear.

The waist circumference (WC) was measured by a tape measure (Fogelholm et al. 2006a) at a point between the lowest rib and iliac crest, after a normal exhale, and the mean value of two measurements were used. Waist circumference and BMI are interrelated, but waist circumference provides an independent prediction of risk below and above that of BMI (Janssen et al. 2002). This is because body fat that accumulates around the stomach area together with visceral fat poses a greater health risk than fat stored in the lower half of the body.

Body fat (BF) was estimated by measuring skin-fold thickness at seven different anatomical sites (Jackson and Pollock 1985). Body composition determined from skinfold measurements correlates well ($r = 0.70 – 0.90$) with body composition determined by hydrostatic weighing (Jackson and Pollock 1985, ACSM 2000).

4.3.2 Aerobic fitness

In the cross-sectional study I, aerobic fitness was measured by the 12-min running test (Cooper 1968) performed mainly outdoors. In the winter, however, some garrisons had the possibility to arrange tests indoors as it is recommended. The test timing and circumstances were standardized according to an expert supervisor. Conscripts were instructed to perform the 12-min run with a maximal effort but at a progressively increasing running speed. Subjects were allowed to stop the test at any time for safety purposes. The accuracy of the measurements was ±10 meters.

In the training study II, maximal oxygen uptake (VO_2max) was measured using a bicycle ergometer (Ergoline GmbH, Ergoline, Germany). The initial work load of the test was 50 W, and it was increased by 25 W every second minute until exhaustion (MILFIT/FitWare, Fitware Oy, Mikkeli, Finland). Oxygen uptake (VO_2) was measured continuously using a gas analyzer (SensorMedics, Yorba Linda, California, USA). Blood samples were taken from a fingertip every second minute to measure blood lactate concentrations by the Biosen C line Sport (EKF Diagnostics, Barleben/Magdeburg, Germany). Heart rate was recorded continuously using heart rate monitor (Polar Electro, Kempele, Finland). Volitional exhaustion was the main criterion indicating that VO_2max was achieved, and the highest mean VO_2 over one minute was accepted as VO_2max. The subject's exhaustion was ensured by the following two basic criteria 1) a respiratory exchange ratio (RER) above 1.05, and 2) perceived exertion (RPE) more than 17.

FIGURE 1 Measurement of maximal oxygen uptake (VO_2max) using the bicycle ergometer (Ergoline GmbH, Ergoline, Germany).

4.3.3 Muscle fitness

The subjects were carefully familiarized with the testing procedures and techniques. In all tests of physical performance strong verbal encouragement was given to each subject (studies I, II, III).

4.3.3.1 Muscle endurance

Muscle endurance tests (study I) consisted of sit-ups (Viljanen et al. 1991) and a back muscle test to test the endurance of abdominal, back and hip flexor muscles. Push-ups (ACSM 2000) and pull-ups (Schmidt 1995) were used to test physical performance of the upper extremities and a standing long jump (Bosco et al. 1983) was used to test explosive force production.

Sit-ups, to measure performance of abdominal and hip flexor muscles, were done so that in the starting position the subjects were lying on their back on the floor with their hands behind their neck with their elbows pointing forward. The knees were flexed at the angle of 90 degrees, the legs were slightly abducted and the assistant supported the ankles. During the movement, the subjects lifted their upper body and brought their elbows to the knee. The result of this test was expressed as a number of sit-ups during 60 s (Viljanen et al. 1991).

Push-ups, to measure performance of arm and shoulder extensor muscles, had subjects starting with their hands shoulder-width apart, fingers pointing forwards, legs parallel and in the lowest push-up position. During the movement, the arms were fully extended and the torso was straight. In the second phase, the torso was lowered down to the elbow angle of 90 degrees. The results of this test were expressed as a number of push-ups during 60 s (ACSM 2000).

Pull-ups, to measure performance of arm and shoulder flexor muscles, pull-ups were started from the lowest position where the subjects hang from a horizontal bar by gripping it with their hands. During the movement, the arms were flexed until the chin was above the bar. Thereafter, the body was lowered down to the starting position, and this movement was repeated continuously as many times as possible without stopping. The results of this test were expressed as a total number of pull-ups (Schmidt 1995).

Back muscle test (back-ups), to measure performance of back and hip extensor muscles. In the beginning, subjects faced down in the lowest position by keeping their hands behind their neck. An assistant supported the legs. During the movement, the upper body was lifted so that the scapulas were 30 cm higher than the shoulder level in the initial position (marked with elastic rope). Thereafter, the upper body was lowered down to the starting position. The result of this test was expressed as a number of back-ups during 60 s.

Standing long jump was used to measure explosive force production of the lower limbs. The jumps were (performed twice) started on the ground with the legs kept nearby each other. Explosive bilateral take off was assisted by a powerful swinging of the upper body and arms. The landing of each jump was performed bilaterally as well. The result of the best jump was expressed as meters of the shortest distance from the landing to the starting line (Bosco et al. 1983)

The recovery time between each test was at least five minutes. Before testing, supervisors showed and taught the technically correct way to perform each test. Performance technique of each conscript was controlled by the supervisors as well. The absolute result for each muscle fitness test was scored to corresponding fitness categories from 0 (poor) to 3 (excellent). Thus, the total muscle fitness index (MFI) was the sum of 5 muscle fitness tests (Table 4).

TABLE 4 Scoring of individual physical fitness tests and muscle fitness index (MFI).

	Fitness categories			
	Poor 0 point	**Satisfy 1 point**	**Good 2 points**	**Excellent 3 points**
Muscle fitness test				
a. Standing long jump (m)	< 2.00	2.00	2.20	> 2.40
b. Sit-ups (number)	< 32	32	40	> 48
c. Back-ups (number)	< 40	40	50	> 60
d. Push-ups (number)	< 22	22	30	> 38
e. Pull-ups (number)	< 6	6	10	> 14
MFI - index (a-e) (points)	0 – 4	5 – 8	9 – 12	13 – 15
12 min running test (m)	< 2200	2200	2600	> 3000

4.3.3.2 Muscle strength

In studies II-III maximal isometric force, maximal rate of isometric force development (RFD) and isometric force–time curves of the bilateral leg extensors and upper extremities extensor muscles were measured on an electromechanical dynamometer (Häkkinen et al. 1998b). In the lower extremity measurements, the subjects were in a sited position so that the knee and hip angles were 107° and 110°, respectively. In the upper body bench press tests, the subject was in a supine position with the elbow angle of 90°. In both tests, the subjects were instructed to exert their maximal force and to produce the force as quickly as possible. A minimum of three trials were completed for each subject and the best performance with regard to maximal force was selected for the subsequent statistical analysis.

FIGURE 2 Measurement of maximal isometric force of bilateral arm extension with an electromechanical dynamometer.

The force signal was recorded on a computer and, thereafter, digitized and analysed with a Codas TM computer system (Dataq Instruments, Inc, Akron). Maximal peak force was defined as the highest value of the force. The force-time analysis on the absolute scale included the calculation of average force (N) produced during the time intervals of 0-100, 0-500 and 500-1500 ms from the start of the contraction (Häkkinen et al. 1998b). The maximal RFD was also analysed and defined as the greatest increase in force in a given 50-ms time period (Häkkinen et al. 1998b,c). The reproducibility of the measurement of maximal isometric force is reported to be high (r=0.98, C.V. = 4.1%, Viitasalo et al. 1980). The respective values for the rate of force development have been: r=0.80, C.V. = 17.8% in test-retest comparison (Viitasalo et al. 1980).

FIGURE 3 Measurement of maximal isometric force of the bilateral leg extension with an electromechanical dynamometer.

4.3.4 Electromyography (EMG) (study II)

EMG is a method of recording and quantifying the electrical activity (muscle fibre action potential) produced by the muscle fibres of activated motor units. In the present study EMG activity during bilateral extension of the leg and arm muscles was recorded from the vastus lateralis (VL), vastus medialis (VM) and rectus femoris (RF) muscles of the right leg and from the triceps brachii (TB) of the right arm. Bipolar (20 mm interelectrode distance) surface EMG recording (Beckman miniature-sized skin electrodes 650437, Illinois, USA) was employed. The electrodes were placed longitudinally over the muscle bellies between the centre of the innervation zone and the distal tendon of each muscle. The EMG signal amplification was 500 (Glonner Biomes 2000, Glonner Electronic, München, Germany); cut-off frequency 360 Hz /3 dB^{-1}, and it was digitised simultaneously with the force records at a sampling frequency of 1 kHz (Kyröläinen et al. 2005). The positions of the electrodes were marked on the skin by small ink tattoos (Häkkinen et al. 1998c). These dots ensured the same electrode positioning in each test over the 8-week experimental period. EMGs were fullwave rectified, integrated and time normalized accordingly with the force signals. The maximal peak force phase of the isometric contractions (500–1500 ms) represents also the maximal EMG phase (Häkkinen et al. 1998b,c). In the isometric condition, the reproducibility of EMG has been reported to be very high (r=0.88, Komi and Buskirk 1970; r=0.88-0.91, Viitasalo and Komi 1975; r = 0.95-0.98; C.V. = 3.2-6.9%; Viitasalo and Komi 1978).

4.3.5 Muscle and Fat Thickness (study II)

Muscle and fat thickness of the right triceps brachii (TB), vastus lateralis (VL) and vastus medialis (VM) were assessed before and after the 8-week experimental training by using ultra-sound (Abe et al. 1994, Abe et al. 2000). Scans were obtained on an ultrasound scanner (ALOKA SSD-2000, Japan). The scans were taken at the middle portion of the VL and VM muscles, while subjects were in the supine position with the thigh relaxed. In the TB scans, the subjects were in sitting position with the right arm relaxed and scan was taken at the middle portion of TB. Radiation exposure was minimized by low-exposure factors (125 kVp, 3 s, 180 mAs). All scans were analyzed by the same individual. Muscle thickness was digitized using an image processing and analysis system (ALOKA SSD-2000, Japan). The accuracy of the ultrasound method for estimating body composition is reported to be high (r = 0.79-0.95, Abe et al. 1994, 1996).

FIGURE 4 Measurement of muscle and fat thickness of the right triceps brachii with an ultrasound scanner ALOKA SSD-2000 (Japan).

4.3.6 Field running test (study III)

A three kilometre-field (3K) running test with maximal effort was performed twice on the same cross-country track while carrying the 14.2 kg combat load (battle dress, running shoes, rifle with a sling and combat gear), approximately 19.2% of the body weight. All subjects were instructed to complete the test in the shortest possible time. Heart rate (HR) was recorded continuously using heart rate monitors (Suunto T6, Suunto, Vantaa, Finland). Blood samples were obtained before and after the 3K combat run test. Maximal isometric force of leg extensors and maximal hand grip were assessed before and after the 3K combat run test. Maximal isometric grip strength was measured by the dynamometer (Saehan, Saehan Corporation, Masan, South Korea) in a sitting position. The elbow was flexed at the 90° position. The best result of the right and left hands was chosen as the outcome (Fogelholm et al 2006a).

4.3.7 Questionnaire (study II)

All the subjects answered questions with regard to their education, smoking and alcohol drinking habits, sleeping behaviour, sick leaves, and a previous level of leisure-time physical activity. One question (single-item question on leisure-time vigorous physical activity (SIVAQ)) on this questionnaire was, "Think about a previous 3-month period before the military service and consider all leisure-time physical activity with duration of at least 20 min. What was the frequency of your physical activity?" The alternatives were 1) less than once a week; 2) no vigorous activities but light or moderate physical activity at least once a week; 3) vigorous activity once a week; 4) vigorous activity twice a week; 5) vigorous activity three times a week; and 6) vigorous activity at least four times a week (Fogelholm et al. 2006b). Upon further analysis, the alternatives 1 and 2 were combined as an inactive group, 3 and 4 as a moderate activity group and 5 and 6 an active group.

4.3.8 Blood analyses (study II, III)

Blood samples were drawn from an ulnar vein during the first (PRE) and the ninth (POST) weeks of the BT season. Both blood samples were taken at 6:30 in the morning after an overnight fast (IV). Acute blood samples were drawn from the ulnar veins (V) before the field running test and just after the test. Serum total growth hormone (GH) was analyzed (1235 Wallac™AutoDelfia, Wallac Oy, Turku, Finland) using time-resolved fluoroimmunoassay (Auto-Delfia®hGH, Wallac Oy, Turku, Finland). The sensitivity and intra-assay variance for this assay was up to <0.026 mIU/l and 4.9%.

Serum total testosterone (TEStot), cortisol (COR), thyroxine (T4), and sex hormone-binding globulin (SHBG) were analyzed by Vitros ECi (Ortho Clinal Diagnostic, NY, USA) using respective commercial luminoimmunoassays (Ortho-Clinical Diagnostic, Amersham, UK). The sensitivity and intra-assay coefficient of variance for these assays were, 0.5 nmol · L^{-1} and 5.7% and <5.5 nmol · L^{-1} and <5.8%, 3.9 pmol · L^{-1} and <2.6%, and 0.2 nmol · L^{-1} and <2.4%, respectively. The TES/COR and TES/SHBG ratios were also calculated. Blood lactate (B-La) was analyzed from fingertip blood samples (Lactate Pro, Arkray, Japan). Its coefficient of variance (CV) was 3%.

4.4 Statistical methods and analysis

In study I, the results were expressed as means of the weighted means, which were collected from all garrisons. Further statistical analyses were done by using logistic regression (multinomial and cumulative logistic models). Explanatory variable was a year which was used either as a continuous or a classified variable. The level 'good' and the first studied year were used as a reference category when appropriate. The significance between physical fitness test class distributions has been analyzed by the chi square test. Correlation coefficients were calculated by the Spearman method. P-value less than 0.01 were defined as significant.

In study II-III standard statistical methods were used for the calculation of means, standard deviations (SD), and Pearson product moment correlation coefficients. Assumptions were not met, even with transformations, to perform a repeated ANOVA -testing. Therefore, the following separate methods were used to analyze the data. For two dependent time-points paired t-tests and nonparametric Wilcoxon tests were utilized. When testing differences between three groups, univariate ANOVA procedure (with LSD and Bonferroni multiple comparisons) or Kruskal-Wallis nonparametric test (with Mann-Whitney U-tests as pair wise comparisons) were appropriate. The $p<0.05$ criterion was used for establishing the statistical significance.

5 RESULTS

5.1 Aerobic fitness, muscle endurance and body composition profiles of conscripts from 1974-2004 (study I)

The mean body mass of the conscripts increased from 70.8 kg to 75.2 kg ($p<0.001$) between the years 1993-2004. Thus, the overall gain of body mass was 4.4 kg (5.9%). At the same time, the mean body height increased by 0.6 cm (0.3%).

The mean distance run by conscripts in the 12–min running test increased from 2650 m to 2760 m (4%) between the years 1975-1979 (Figure 5). Thereafter, it decreased by 12% to 2434 m in 2004 ($p<0.001$). The number of subjects who ran less than 2200 m decreased by 57% ($p<0.001$) during the first study phase (1975-1979), but increased 5.6-fold by 2004 ($p<0.001$). During the same time periods, the number of subjects who ran more than 3000 m first increased by 51%, but thereafter, a 3.9–fold decrease was observed (both, $p<0.001$). The mean running distance during the 12-min running test correlated inversely with mean body mass ($r = -0.89$, $p<0.001$).

The relative number of conscripts who achieved excellent and good muscle fitness index (MFI) increased ($p<0.001$) from 56.5% to 66.8% during the years 1982-1992. Thereafter, it decreased ($p<0.001$) gradually to 41.2% in 2004. Simultaneously, the number of subjects who had poor MFI showed the opposite pattern of change (from 16.5% in 1982 to 8.1% in 1992 and then to 25.2% in 2004, $p<0.001$). No relationship between body mass and MFI was observed.

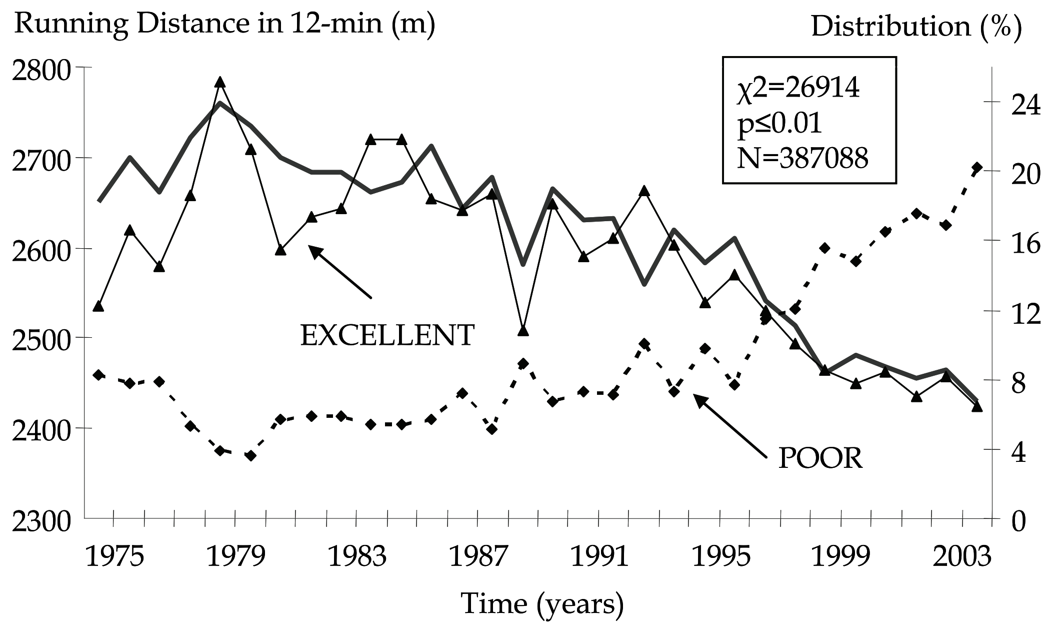

FIGURE 5 Average distances of 12 minute running test during 1974-2004. The thick solid line represents the mean values, while the thin solid line with triangles represents the relative distribution of excellent results, and the dashed line with squares represents the poor results. All values have been compared to the year 1974.

5.2 Changes in cardiovascular performance during the basic training period (study II)

5.2.1 Body composition

In the beginning of the BT season, no initial differences between the groups were observed with respect to age, height, body mass, physical activity, muscle strength or aerobic capacity. The changes in body composition, muscle thickness and the muscle fat thickness variables are shown in Table 5.

All training groups decreased their BF as follows, the ST group by 16.3% ($p<0.001$), the ET group by 5.2% ($p<0.01$) and the NT group by 9.5% ($p<0.01$) after the 8-week training period. Furthermore, significant decreases were recorded in BM, BMI, WC values of the ST group by 1.1% ($p<0.05$), 1.1% ($p<0.05$), and 2.9% ($p<0.001$), respectively. Both BM and BMI remained unaltered in the ET and NT groups, whereas significant decreases were observed in WC of the ET group by 2.6% ($p<0.01$), but not in the NT group.

No significant changes were observed in the muscle thickness or in the muscle fat thickness of VL and VM in the ST, ET and NT groups (Table 5). The muscle thickness of TB decreased significantly by 6.1% ($p<0.05$) and 5.7% ($p<0.01$) in the ET and NT groups, respectively, while no change was observed in the ST group. Correspondingly, the fat thickness of TB in the ST and NT groups decreased significantly by 7.1% ($p<0.01$) and 5.6% ($p<0.05$), while no change was observed in the ET group. No significant differences in the changes between the groups in body composition, muscle or fat thickness variables were observed after the 8-week training period.

TABLE 5 Changes in body composition and muscle thicknesses during an 8-week BT season (*p<0.05, **p<0.01, ***p<0.001).

	Pretraining (0 weeks)			**Posttraining (8 weeks)**		
	Strength (21)	Endurance (20)	Normal (22)	Strength (21)	Endurance (20)	Normal (22)
Mass (kg)	76.5±15.3	75.5±12.2	69.7±8.5	75.5±14.1*	75.0±10.0	70.3±7.8
Fat (%)	10.3±5.1	10.3±4.6	9.8±3.9	8.5±4.0***	9.3±3.4**	8.7±3.4**
BMI	24.0±4.9	23.2±3.7	21.9±2.2	23.6±4.5*	23.1±3.0	22.0±2.0
WC (cm)	83.0±12.5	83.5±10.4	80.0±6.0	80.4±10.6***	80.9±6.7**	78.7±5.4
Muscle thickness						
VL (cm)	2.28±0.37	2.42±0.37	2.29±0.28	2.31 ±0.33	2.47 ±0.38	2.33 ±0.29
VM (cm)	1.57±0.38	1.89±0.38	1.63±0.22	1.60 ±0.34	1.89 ±0.34	1.64 ±0.21
TB (cm)	2.54±0.38	2.80±0.69	2.47±0.43	2.37 ±0.37*	2.79 ±0.64	2.31±0.39**
Fat thickness						
Thigh (cm)	0.80±0.48	0.76 ±0.38	0.64 ±0.24	0.80 ±0.43	0.80 ±0.37	0.69 ±0.25
Arm (cm)	1.23±0.57	1.19 ±0.52	1.17 ±0.31	1.12±0.48**	1.17 ±0.42	1.11±0.35*

5.2.2 Aerobic fitness

During the 8-week training period, the ET group increased their VO_2max by 8.5% ($p<0.05$), whereas the ST group increased by 12.0% ($p<0.01$, Figure 6) and the NT group by 13.4% ($p<0.001$). In the total subject group, VO_2max improved by 10.5% ($p<0.01$) during the 8-week training period. A significant correlation ($r=-0.56$, $p<0.001$) was observed in the total group of subjects between the initial level of VO_2max and its changes during the 8-week training period.

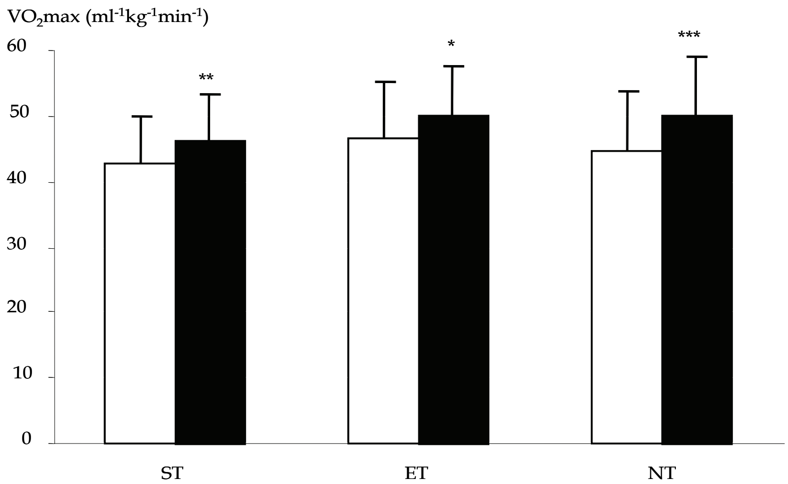

FIGURE 6 Means (± SD) maximal oxygen uptake (VO_2max) measured using a bicycle ergometer test in the strength (ST), endurance (ET) and normal training (NT) groups before (white bars) and after (black) the 8-week training period (*$p<0.05$, **$p<0.01$, ***$p<0.001$).

Correspondingly, the ET, ST and NT groups also increased their maximal aerobic cycling power (W_{max}) by 4.2, 5.5, and 4.8% ($p<0.01$-0.05), respectively (Table 6). At the submaximal working loads of 125-225 W, significant increases ($p<0.01$-0.05) in VO_2max were observed in the NT group, while no changes were observed in the ET and ST groups. Significant decreases in blood lactate accumulation were observed in the ST ($p<0.01$-0.05) and NT ($p<0.05$) groups at the submaximal working loads of 100-150 W, while no significant changes were observed in the ET.

TABLE 6 Endurance capacity values before and the 8-week training period. TTE refers to the total time to exhaustion (*p<0.05, **p<0.01, ***p<0.001).

	Pretraining (0 weeks)			Posttraining (8weeks)		
	Endurance (n=20)	Strength (n=21)	Normal (n=22)	Enduran ce	Strength	Normal
VO_2max ($l \cdot min^{-1}$)	3.5 ± 0.6	3.2 ± 0.6	3.1 ± 0.6	3.7 ± 0.5*	3.5 ± 0.6*	3.5± 0.6***
HRmax (beats/min)	194 ± 7	192 ± 9	192 ± 9	196 ± 8	189 ± 9	188 ± 11*
La_{peak} ($mmol \cdot l^{-1}$)	13.2 ± 2.1	12.9 ± 3.0	13.0 ± 2.5	13.1 ± 1.6	13.0 ± 3.0	12.3 ± 2.4
Pmax (W)	272 ± 41	236 ± 43	224 ± 37	282 ± 35*	246 ± 36**	234 ± 34*
TTE (min)	19.49± 3.20	17.01± 3.26	16.08± 2.54	20.57± 3.04***	17.51± 2.54**	16.52± 2.44*

Significant differences between the groups in TTE and Pmax

5.2.3 Associations between physical activity, physical fitness and sick leaves

Before military service (the preceding 3 months), the proportion of subjects with no leisure time physical activity was 14.3% (SIVAQ alternatives 1-2), with a moderate level of physical activity 44.4% (alternatives 3-4), and with a high level of physical activity 41.3% (alternatives 5-6). The mean initial VO_2max among the inactive subjects (n=9) was 41.3±6.7 $ml \cdot kg^{-1} \cdot min^{-1}$, while it was 43.6±8.0 $ml \cdot kg^{-1} \cdot min^{-1}$among the subjects who were considered moderately physically active (n=28), and 47.0±9.2 $ml \cdot kg^{-1} \cdot min^{-1}$ for physically active subjects (n=26). Inactive subjects increased their VO_2max during BT by 19.4% ($p<0.001$), while the subjects that were considered moderately physically active increased VO_2max by 10.9% ($p<0.001$), and the physically active subjects by 7.8% ($p<0.05$). The difference in VO_2max between the inactive subjects and the active subjects was only 1.8% after the 8-week training period, while before the training period it was 12.1%.

Inactive subjects also increased their maximal voluntary bilateral isometric leg extension force during BT by 15.3% ($p<0.05$), while the moderately physically active subjects increased by 8.2% ($p<0.05$) and the active subjects by 7.4%. The difference in maximal voluntary bilateral isometric leg extension force between the inactive subjects and the active subjects was only 7.4% after the 8-week training period, while before the training period it was 19.0%. Inactive subjects also increased their maximal voluntary bilateral isometric force of the arm extensors during BT by 14.7% ($p<0.001$), while the moderately physically active subjects increased by 12.1% ($p<0.001$) and the active subjects by 8.8% ($p<0.001$). The difference in maximal voluntary bilateral isometric force of the leg extensors between the inactive subjects and the active subjects was

21.7% after the 8-week training period, while before the training period it was 14.4%.

The lower VO_2max seemed to be associated with a higher rate of absences due to being sick during the basic training period. Mean VO_2max of the subjects with no sick absence days (n=32) was 46.9±9.1 $ml \cdot kg^{-1} \cdot min^{-1}$, while the mean VO_2max of the subjects with at least three sick absence days (n=19) was 40.5±5.1 $ml \cdot kg^{-1} \cdot min^{-1}$. Nevertheless, no differences between the training groups with regard to the total number of the sick absence days were observed.

5.3 Changes in maximal and explosive strength, EMG and muscle thicknesses during the basic training period (study II)

The ET and ST groups increased their maximal voluntary bilateral isometric leg extension force by 12.9% ($p<0.01$) and 9.1% ($p<0.05$) respectively, while no significant increase occurred in the NT group (5.2%, p=0.45, Figure 7). These relative increases did not, however, differ significantly between groups. In the total subject group, an increase of 8.9% ($p<0.01$) in muscle strength was recorded.

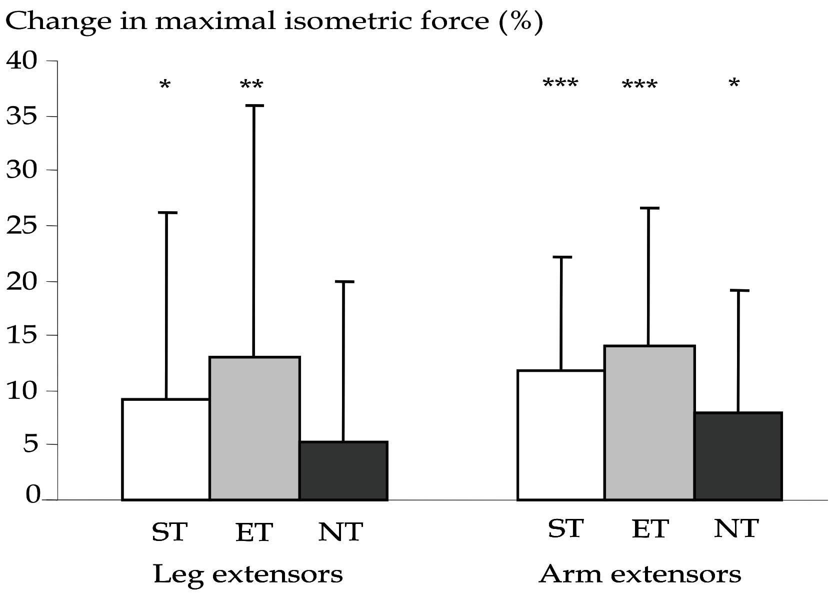

FIGURE 7 Mean (±SD) relative changes (%) in maximal voluntary bilateral isometric leg extension force and in maximal voluntary bilateral isometric arm extension force (bench press) in the strength (ST, white bar), endurance (ET, grey bar) and normal training (NT, black bar) groups during an 8-week training period (*p<0.05, **p<0.01, ***p<0.001).

No significant changes were observed in the maximal bilateral RFD of leg extensors in the ST, ET or NT groups (Table 7). No significant increases were noticed in the force time curves during the time intervals of 0-100 ms and 0-500 ms. Maximum EMG of the leg extensors (VL, VM or RF muscles) also remained unchanged during the bilateral isometric leg extension after the 8-week training season (Table 7).

TABLE 7 Maximal rate of force development and average maximal electromyographic activity (EMG) of leg and arm extensors during the maximal force phase of the isometric action (500-1500 ms) before and after the 8-week training period (*p<0.05, **p<0.01, ***p<0.001).

	Pretraining (0 weeks)			**Posttraining (8weeks)**		
	Strength (n=21)	**Endurance (n=20)**	**Normal (n=22)**	**Strength**	**Endurance**	**Normal**
Maximal RFD ($N \cdot s^{-1}$), legs	14809 ±4949	14133 ±4703	12791 ±4042	13761 ±4794	14138 ±5051	12587 ±3985
Vastus lateralis						
EMG (μV) 500-1500 ms	710 ±218	668 ±176	770 ±285	711 ±295	670 ±139	746 ±245
Vastus medialis						
EMG(μV) 500-1500 ms	789 ±380	677 ±297	710 ±228	816 ±419	703 ±269	764 ±233
Rectus femoris						
EMG (μV) 500-1500 ms	630 ±338	450 ±237	681 ±301	597 ±339	452 ±190	696 ±297
Triceps brachii						
Maximal RFD ($N \cdot s^{-1}$)	5730 ±2772	6636 ±4417	5793 ±2156	6815* ±2678	5991 ±3174	6444 ±1808
EMG (μV) 500-1500 ms	1164 ±673	1172 ±626	1313 ±676	1547** ±881	1599*** ±787	1317 ±914

The individual changes in EMGs of the VL and VM muscles in the maximum force phase (500-1500 ms) correlated positively with the changes in respective maximal force (r=0.76, p<0.001) in the ST group (Figure 8).

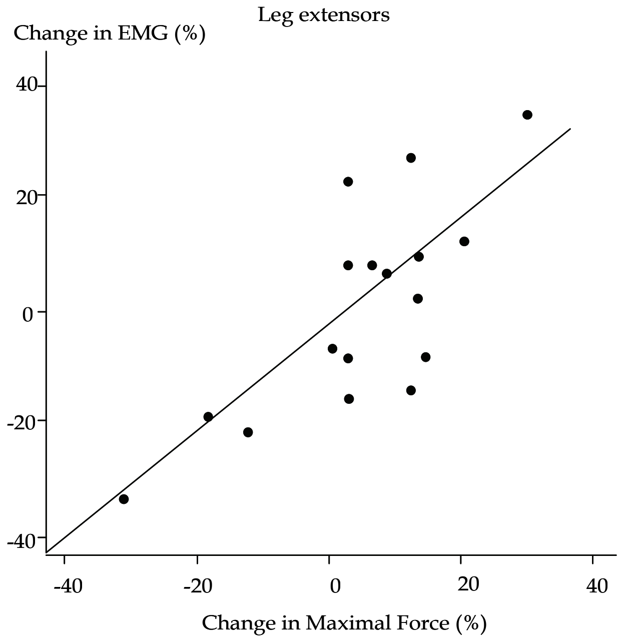

FIGURE 8 The relationship between the relative changes in average maximal EMG of the VL and VM muscles and isometric force of the leg extensors during the 8-week training period in the ST group.

All training groups increased their maximal voluntary bilateral isometric force production of the arm extensors (Figure 7) as follows: ET by 13.9% (p<0.001), ST by 11.8% (p<0.001) and NT by 7.8% (p<0.05). These relative increases did not, however, differ significantly between the groups. In the total group of subjects, maximal force of the arm extensors improved by 11.1 % (p<0.001) during the 8-week training period. A significant correlation (r=-0.58, p<0.01) was observed between the initial level of maximal isometric force of the arm extensors in ST and its changes during the 8-week training period.

Significant changes were observed in maximal RFD of the upper extremities in the ST group by 28.1% (p<0.05, Table 7), while no changes were recorded in the ET and NT groups. Correspondingly, significant increases occurred in the force production of the bilateral arm extensors during the time interval of 0-500 ms in the ST and NT groups by 23.8% (p<0.001) and 13.2% (p<0.05), respectively, while no changes were noticed in the ET group. Significant increases took place in the maximum EMG of TB during the time intervals of 0-500ms and 500-1500 ms: in the ST group by 34.4% (p<0.01) and 37.2% (p<0.01), in the ET groups by 38.6% (p<0.01) and 47.95% (p<0.001), respectively (Table 7), while no changes were observed in the NT group.

5.4 Serum hormone concentrations (study II)

Significant increases were observed in serum basal TES concentration in all training groups after 8 weeks of basic training as follows; ST by 16.3%, ET by 26.6%, and respectively NT by 16.6% (Figure 9). The increase in the ET group differed significantly ($p<0.05$) from the ST and NT groups. Baseline TES concentrations correlated with changes in TES concentration in ST ($r=-0.58$, $p<0.05$) and ET ($r=-0.65$, $p<0.05$) groups during the 8-week training period, while no significant correlation was observed in the NT group. No significant correlations were observed between baseline TES and the changes in strength or endurance performance. No increase was observed in serum basal TES concentrations of the inactive subjects, while significant increases were recorded in the moderately active (22%, $p<0.001$) and active subjects (18%, $p<0.01$), respectively.

Serum basal COR concentration increased significantly in the ST group by 11.1%, while no changes were observed in the ET and NT groups (Figure 9). The increase in the ST group differed significantly ($p<0.001$) from those of the ET and NT groups. None of the training groups showed significant changes in serum basal SHBG concentration (Figure 9).

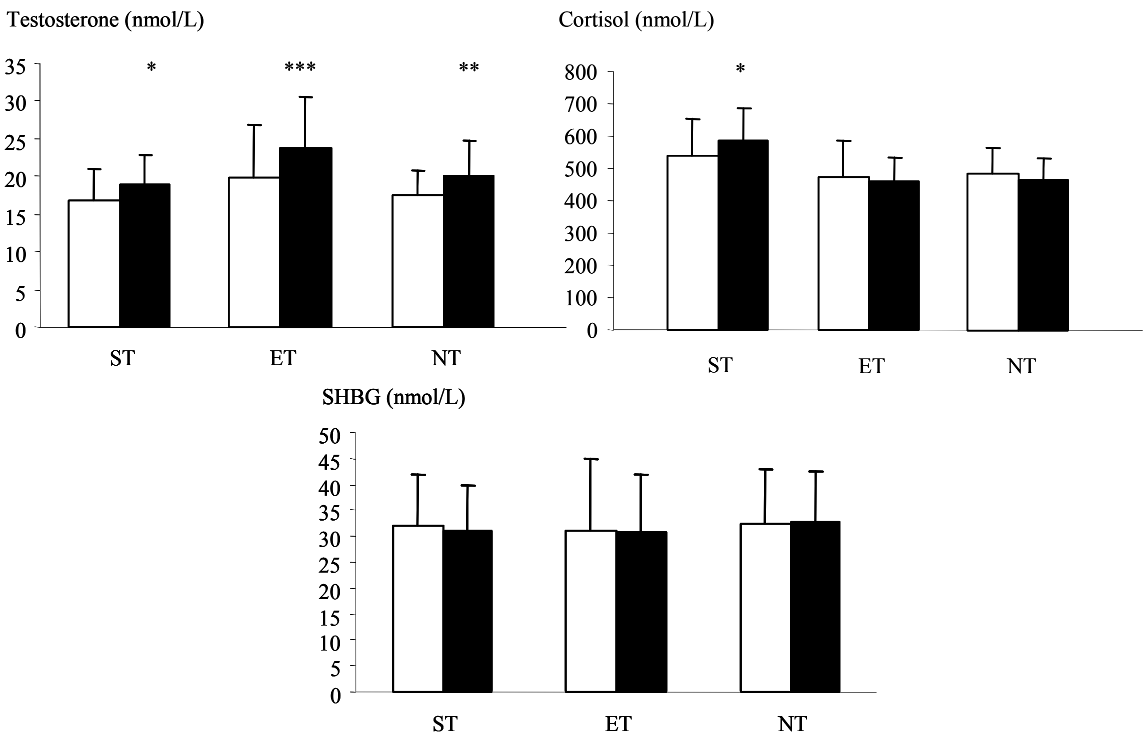

FIGURE 9 Basal serum testosterone (TES), cortisol (COR) and sex hormone binding globulin (SHBG) concentrations before and after the 8-week training period in the NT, ST, ET and groups (PRE = white bar and POST = black bar, *$p<0.05$, **$p<0.01$, ***$p<0.001$).

Significant increases in the TES/COR ratio occurred in ET and NT by 32.8% (p<0.01) and 21.3% (p<0.05), while no changes were noticed in ST (Figure 10). The changes in the NT and ET groups differed significantly (p<0.01) from that of the ST group. All training groups increased their serum TES/SHBG ratio as follows; ST by 19.6% (p<0.05), ET by 23.4% (p<0.05), and NT by 15.2% (p<0.05), respectively (Figure 10). Significant decreases took place in serum thyroxine concentrations in ST by 11.9% (p<0.001), in ET by 10.5% (p<0.05), and in NT by 9.2% (p<0.05), respectively. These relative decreases did not, however, differ significantly between the groups.

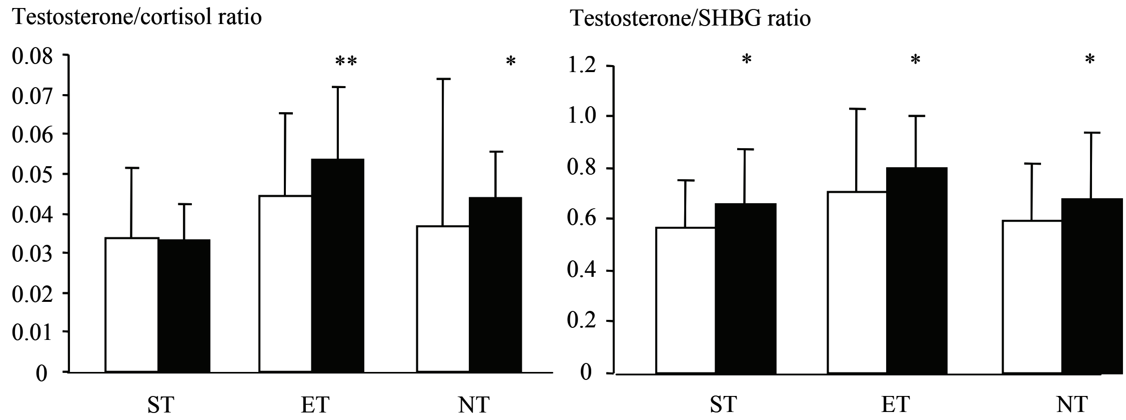

FIGURE 10 Basal serum testosterone/cortisol (TES/COR) and testosterone/ sex hormone binding globulin (TES/SHBG) ratios before and after the 8-week training period in the NT, ST, ET and groups (PRE = white bar and POST = black bar, *p<0.05, **p<0.01).

5.5 Acute physiological responses during the field running test (study III)

All training groups decreased their 3 K field running test time significantly during the 8-week BT period, as follows: ST by 12.4% (p<0.001), ET by 11.6% (p<0.001) and NT by 10.2% (p<0.001, Table 8). No differences were observed between the groups. Table 8 also shows that no significant changes were recorded in HR, although the average HR of a total subject group increased significantly by 2.3% (p<0.05).

TABLE 8 Mean (± SD) times of the field running tests in the strength (ST), endurance (ET) and normal training (NT) groups before and after the 8-week training period (**p<0.01, ***p<0.001).

	Before basic training (0 weeks)			**After basic training (8 weeks)**		
	Strength (n=23)	Endurance (n=18)	Normal (n=21)	Strength (n=23)	Endurance (n=18)	Normal (n=21)
Running time (min)	19.3±3.8	18.3±2.8	18.1±3.0	16.8±3.1***	16.0±2.0***	16.1±2.2***
HR_{max} (beats/min)	188 ± 11	193 ± 9	192 ± 10	189 ± 10	192 ± 9	191 ± 8
Average HR (beats/min)	168 ± 13	176 ± 9	171 ± 18	174 ± 12***	179 ± 8***	179 ± 8***
$B\text{-}La_{post}$ ($mmol \cdot l^{-1}$)	10.1± 2.5	9.8 ± 2.0	10.6 ± 2.4	10.5 ± 2.2	10.1 ± 1.8	9.5 ± 2.0**

Significant increases were observed in the average HR of all training groups as follows: ST from 174±6 to 179±4 bpm (p<0.001), ET from 179±5 to 182±3 bpm (p<0.001) and NT from 179±6 to 184±3 bpm (p<0.001, Figure 11), after comparing to pre- and post-tests during the last 400 s of the field running. No differences between groups were noticed in this regard. The blood lactate values decreased from 10.6±2.4 ($B\text{-}La_{pre}$) to 9.5±2.0 mmol·L-1 ($B\text{-}La_{post}$) (p<0.01) in NT when comparing the pre- and post-tests, while no significant changes were observed in the ST or ET groups (Table 8).

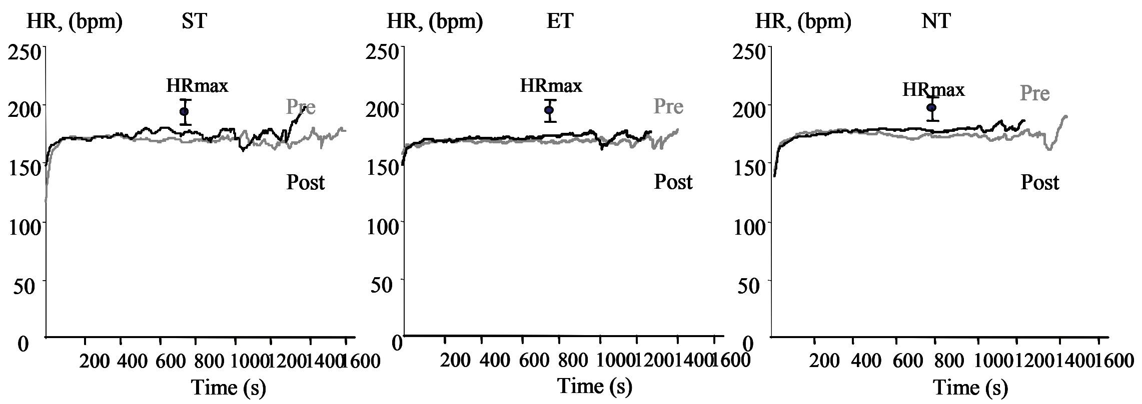

FIGURE 11 Average heart rates (mean± SD) during the field running tests in the strength (ST), endurance (ET) and normal training (NT) groups pre-test (grey line) and post-test (black line) the 8-week training period including HRmax (mean± SD) values measured during the first VO_2max test .

The 3K field running tests (pre- and post) induced significant decreases in maximal isometric force ($p<0.01$-0.05) as follows: ST by 7.4% ($p<0.05$) and 5.3% ($p<0.05$), ET by 6.6% ($p<0.05$) and 9.6% ($p<0.05$), NT by 15.8% ($p<0.001$) and 9.3% ($p<0.05$). The decreases in maximal isometric force of the leg extensors in the NT group differed from those ones in the ST and ET groups. A significant decrease was also observed in hand grip force ($p<0.01$) of the ET group, while no significant decreases were noticed in the ST and NT groups.

Pre- to post- run test acute responses in serum TES were significantly increased both at pre- and post- training test time points in all training groups as follows: ST by 25.1% ($p<0.001$) and 16.4% ($p<0.001$), ET by 26.5% ($p<0.001$) and 30.0% ($p<0.001$) and NT by 24.4% ($p<0.001$) and 31.1% ($p<0.001$, Figure 12). However, the serum TES post-training acute response of the NT group was higher ($p<0.05$) when compared to that of the pre-training testing time point. However, no significant differences in the response patterns among the different training groups were observed. Figure 12 also demonstrates that serum GH concentrations increased significantly ($p<0.001$) after the 3K loaded combat run test in all basic training groups at both the pre- and post training testing time points. The acute post-training responses in both the ST and ET groups were significantly higher in the post-test time point compared to pre-test time point. In addition, NT differed in terms of the training-induced GH responses from the ET and ST groups. Acute serum COR responses were significant both during pre- and post-tests in all training groups as follows: ST by 45.3% ($p<0.001$) and 44.2% ($p<0.001$), ET by 45.7% ($p<0.001$) and 14.1% ($p=0.10$), NT 70.5% ($p<0.001$) and 49.0% ($p<0.001$). Post-training acute responses of ET and NT were significantly lower than those of pre-tests testing time point (Figure 12).

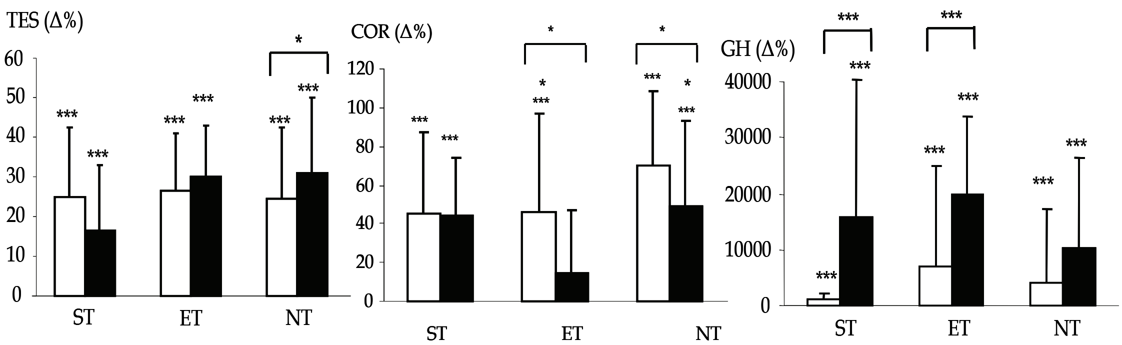

FIGURE 12 Mean (± SD) relative changes of serum testosterone (TES), cortisol (COR), and growth hormone (GH) concentrations pre to post 3 K run before and after the 8-week training period in the NT, ST, and ET groups (Pre, white bar and Post, black bar; * P<0.05, ** P<0.01, *** P<0.001).

Significant correlations were observed between the initial level of VO_2max and decreases in field running test time during the 8-week training period in ST (r=-0.63, $p<0.01$) and ET (-0.46, $p<0.05$), while no significant correlation was observed in NT ($r=-0.36$, $p=0.14$). A significant correlation was observed for the total subject population in this study ($r=-0.49$, $p<0.001$) between the initial level of VO_2max and decreases in field running test time (Figure 13). A significant correlation was also observed between the initial VO_2max values and initial field running test times ($r=-0.66$, $p<0.001$) in a total subject group. However, the correlation was low ($r=-0.22$, $p=0.10$) between individual changes in VO_2max values and changes in the field running test times of a total subject group during the 8-week training period. Furthermore, a significant correlation was observed between the initial level of maximal isometric force production of leg extensors and decreases in field running test time during the 8-week training period in the ST group ($r=-0.66$, $p<0.01$), while no significant correlation was observed in the ET group ($r=-0.38$, $p=0.13$) or the NT group ($r=-0.39$, $p=0.21$) groups.

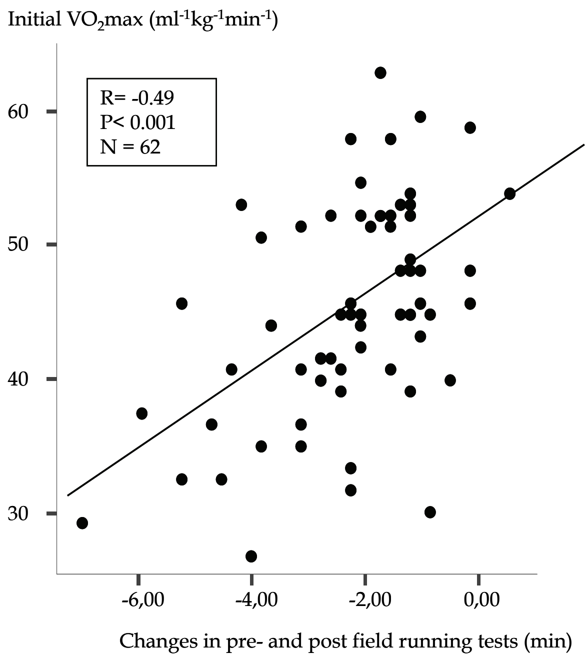

FIGURE 13 Relationship between the initial maximal oxygen uptake (VO_2max) and relative changes in field running tests during the 8-week basic training period.

6 DISCUSSION

6.1 Physical fitness profile of conscripts in Finland (study I)

The present study I (paper I) demonstrated clearly that aerobic fitness of Finnish young men has decreased during the years 1975-2004. In addition, the study demonstrated that the number of subjects who ran less than 2200 m in the Cooper test (12-min run) has increased 5.6-fold from 1980-2004. During the same time period, the number of subjects who could run more than 3000 m has decreased 3.9-fold. When this is calculated as changes in running distance during the 12-min run, the decrease in aerobic capacity has been 12% a percentage that corresponds to the calculated values of 50.4 $ml \cdot kg^{-1} \cdot min^{-1}$to 43.2 $ml \cdot kg^{-1} \cdot min^{-1}$ (Cooper 1968). It must be emphasized that these values of maximal oxygen uptake (VO_2max) are only estimations based on indirect, predictive techniques, nevertheless, they seem to be rather highly comparable to the direct determinations of VO_2max (r=0.897) (Cooper 1968). The sample of the present population-based study represents virtually all Finnish men at the age of 20 years, while during the years 1975-2004 almost 95% of the age groups began their compulsory military service.

The estimated VO_2max of 50 $ml \cdot kg^{-1} \cdot min^{-1}$ in the Finnish conscripts at the end of 1970's is almost the same as those of the USA army male recruits during the pre-initial recruit training (51 $ml \cdot kg^{-1} \cdot min^{-1}$) (Vogel et al. 1986) or Canadian (49 $ml \cdot kg^{-1} \cdot min^{-1}$) (Macnab et al. 1969) or Japanese (51 $ml \cdot kg^{-1} \cdot min^{-1}$) (Matsui et al. 1972) students at the same time period. On the other hand, Sharp et al (2002) have reported that the recruits entering basic training in the US-army in 1978 were as aerobically fit as those entering in the year of 1998. However, Knapik et al (2006) later reported that slower running times on 1-mile and 2-mile tests indicate decreases in recruit's aerobic performance during the years of 1987-2003.

During the years 1993-2004 the mean body mass of conscripts has increased almost 5 kg without a significant change (+0.6 cm) in body height. At the same time, body mass was inversely associated with aerobic fitness. The present results are well in line with earlier findings of Kautiainen et al (2002) who demonstrated that the prevalence of overweight and obesity has significantly increased among the adolescents in Finland between the years of 1977 to 1999. In addition, the relative number of conscripts who achieved poor muscle endurance result has increased 3.1-fold from 1983 to 2004. Decreased muscle endurance, aerobic fitness and obesity have been shown to increase the risk factors for musculoskeletal injuries among the conscripts (Jones and Knapik 1999). Furthermore, a fourfold higher injury rate has been reported in previously untrained soldiers compared with the well-trained soldiers (Rosendahl et al. 2003). Slight increases in musculoskeletal injuries and in exemption from the military service have also been observed among Finnish conscripts over the last few years (CDDS 2003-2007).

The primary finding of the study (I), showed gradually decreased aerobic fitness over the years from 1975 until 2004. This phenomenon is supported by the decrease observed in physical activity level among the Finnish adolescents (Telama et al. 1997). However, the reasons for the decline of the physical fitness of adolescents are not clear. It is obvious, that decreased hours of physical education in school curricula has contributed to this negative development in the physical fitness of pupils and adolescents in all social groups (Tammelin et al. 2003). These findings are supported by Trost et al (2002), who have reported rapidly declining physical activity among the children and adolescents in a population-based study of Australian students. At the same time, adolescents are watching more and more television and playing with various computer games (Giammattei et al. 2003). In addition, the popularity of sporting events that develop endurance has decreased (Tammelin et al. 2003). Tammelin et al (2007) also reported that only 23% of boys and 10% of girls between the ages of 15-16 years performed at least 60 min of moderate-vigorous physical activity per day. In addition, 48 percent of boys and 44 percent of girls reported more than 2 h of daily TV viewing. High amounts of TV viewing and computer use were associated with lower levels of physical activity in both genders. Furthermore, Kantomaa et al (2008) have demonstrated that physical inactivity was associated with several emotional and behavioural problems like anxious and withdrawn depressed symptoms, social, thought problems and attention problems in adolescents.

Therefore, if the decrease in physical activity and subsequently, physical fitness, combined with the increase in body mass continues among children and young adults, the incidence and prevalence of several diseases will increase as well. Kesäniemi et al (2001) have concluded that regular physical activity and good physical fitness are in association with reduced risk of cardiovascular diseases, coronary strokes, hypertension, type 2 diabetes, osteoporosis, obesity, colon cancer and breast cancer, anxiety and depression.

In summary, this study has revealed that aerobic fitness and muscle endurance of young men has decreased and body mass has increased during the last 15 years in Finland. These negative phenomena may cause serious health problems among whole population in the future.

6.2 Cardiovascular and neuromuscular adaptations to added endurance and strength training (study II)

6.2.1 Cardiovascular adaptations (paper II)

The 8-weeks of endurance and strength training in combination with the current standardized BT including physical, combat and marching significantly improved VO_2max in both ET and ST training groups, as well as in the NT group. However, no significant differences were observed between the groups. The ET and ST groups showed greater improvements in time to exhaustion than the NT group. In addition, positive changes were observed in body composition, since body fat and waist circumference decreased in all groups during BT.

Higher levels of physical activity over 3 months prior to entering military service (SIVAQ), was associated with better initial cardiorespiratory function and smaller improvements in VO_2max during BT. Correspondingly, the inactive subjects showed the greatest improvements (19%) in their VO_2max values. In addition, the difference in the VO_2max values between the active and inactive subjects was reduced by 10% in comparison to the initial values. Thus, inactive subjects obtained almost the same fitness level as the active subjects during the 8-week training period. This is well in line with findings of Hickson & Rosenkoetter (1981) who found that greater improvements in VO_2max can be achieved when the initial VO_2max is lower as with untrained subjects. Interestingly, the present subjects with higher initial VO_2max also had less sick absence days than those with a lower VO_2max. Some other studies have also demonstrated a link between lower aerobic capacity, muscle fitness and obesity, which are risk factors for musculoskeletal injuries among the conscripts (Milgrom et al. 1985, Jones et al. 1999, Gomes-Merino et al. 2003).

The present study revealed that higher initial VO_2max values were related to lower changes in VO_2max induced by the 8 weeks training period. In addition, the statistical analysis showed that the subjects with higher than 55.5 $ml \cdot kg^{-1} \cdot min^{-1}$ of VO_2max did not improve their maximal aerobic capacity. In this case, it is possible that the intensity of the military training was not high enough for positive responses in VO_2max, an observation consistent with the study by Dyrstad et al (2006). The authors explained that the poor improvements observed in soldier's aerobic fitness were due to the low amount of high-intensity endurance training during military service. Furthermore, the special ST programme combined with BT positively enhanced the aerobic capacity of the conscripts. Thus, strength training 3 times a week did not appear to lead to any interference with the development of VO_2max, since the improvements in VO_2max in the ST group was similar than in the ET group. This is well in line with previous data e.g. by Bell et al (2000) who observed that increases in VO_2max were similar between concurrent strength and endurance training and endurance training only during a 12-week training intervention. Thus, it could be useful to have some more strength training in the BT programme, because strength training has been shown to have a positive influence on the conscripts' VO2max values and also on the prevention of the bone stress injuries. As mentioned earlier, several studies have demonstrated that the soldiers with poor aerobic fitness and muscle strength levels had a significantly increased risk of bone stress injury (Jones and Knapik 1999, Hoffman et al. 1999, Mattila et al. 2007). However, if training programmes emphasized too much endurance training during BT, it may elevate the injury risk. A high volume of running mileage has, for example, been shown to increase injury risk, especially during the initial weeks of military training (Jones and Knapik 1999, Knapik et al. 2001).

In summary, the present BT programme in the Finnish Defence Forces, including a high amount of endurance training (physical, combat and march training), is associated with improved cardiovascular performance of conscripts. No further improvements in VO_2max were, however, obtained by specific endurance training 3 times a week. Interestingly, strength training 3 times a week did not lead to interference with the development of VO_2max. BT also positively influenced body composition by decreasing BF and WC but BT alone was not a sufficient enough stimulus to increase maximal strength of the leg extensors. These beneficial changes in aerobic performance and body composition are especially prominent among previously inactive young men. The extent to which improvements in endurance capacity can be obtained throughout the entire military service needs further experimental research work.

6.2.2 Neuromuscular adaptations (paper III)

The 8-week basic training combined with added strength and endurance training significantly improved maximal voluntary isometric force of the arm extensors which was associated with an increase in maximal muscle activation of the trained muscles. Both ST and ET also increased in terms of maximal strength of the leg extensors, while no significant changes occurred in NT. Large interindividual differences were observed in the changes in maximal average EMG of the vasti muscles, and these changes correlated with the changes in maximal force in the ST group. BT training with a large amount of endurance-based military training may have interfered with strength development, especially with the explosive power development of the lower extremities in the ST group. None of the groups showed muscle hypertrophy either in the lower or upper extremities.

BT also positively influenced body composition by decreasing BF and WC but no increases were observed in muscle thickness of the lower and upper extremities. In addition, no changes were recorded in a total body weight. This is well line which earlier findings, which have demonstrated decreases in BF and increases in lean body mass without changes in body weight after prolonged military training regimens (e.g. Vogel et al. 1978, Patton et al. 1980, Faff et al. 2000). Interestingly, significant decreases in muscle thicknesses of the upper extremities in the ET and NT groups were observed during the 8-week

BT. The observation that no increases in muscle thickness occurred, and that ST did not show larger strength development than the other two groups might have been a consequence of the high amount of the endurance based military training during the BT. Moreover, these findings may partly be explained by a low energy intake. Possible energy deficit and the large amount of military based endurance training may have facilitated aerobic metabolism and inhibited protein synthesis leading to somewhat lower strength development than one might expect (Hickson 1980, Kraemer et al. 1995). Dolezal and Potteiger (1998) have shown that 10 weeks of concurrent resistance and endurance training increased daily energy expenditure, aerobic capacity and muscular strength, and decreased body weight, while single-mode training, such as endurance or strength training alone, did not have as large of an effect on energy expenditure and body composition. Therefore, a high amount of endurance-based military training led to possible interference with the hypertrophic effects of strength training on trained muscles, especially, in the ST group. The present military-based endurance training, combined with strength training, may have also included an overtraining aspect as well, and untrained individuals may have been more susceptible to the negative effects of stress than trained individuals (Häkkinen et al. 2003). The overall loading of BT, including some caloric deficit, high energy expenditure, and limited/disrupted sleeping hours, could have been too high for the subjects, especially, in the ST group, since the improvements in strength development and changes in muscle thickness were smaller than expected. In the present study, daily sleeping hours were approximately 7 hours a day, which was 2 hours less than before the military service commenced. This may have negatively influenced the recovery process. On the other hand, Mikkola et al (2009) have demonstrated that military service markedly reduced fat tissue and increased the amount of lean body tissue of the conscripts, especially, among prior inactive subjects with high BMI.

As earlier mentioned, this study has demonstrated that a high amount of endurance-based military training, combined with resistance training, caused some interference with explosive power production of the muscles, especially, in the lower extremities. Maximal voluntary bilateral isometric leg extension force improved in both the ST and ET groups, but not in the NT group. Thus, the overall training load during BT in NT was not a sufficient enough stimulus to increase maximal strength of the lower extremities. The increase in maximal strength observed in ET may be due to the fact that a part of the present endurance training was carried out using cycling, which is known to load the lower extremity muscles (Izquierdo et al. 2004). However, since the increase in strength in ST were not higher than in ET, it is possible that the overall BT programme, including a large amount of endurance training, interfered with strength development in ST. It is known that an interference effect on strength development may occur when the overall volume and/or frequency of training is high (Hickson 1980), whereas low frequency concurrent strength and endurance training leads to large gains in maximal strength (Häkkinen et al.

2003). Häkkinen et al (2003) have suggested that in previously untrained men endurance training combined with strength training seems to lead to interference with explosive strength development. This interference was also associated by limited changes in rapid voluntary neural activation of the trained muscles. The present study groups, including ST, showed no increases in rapid activation of the lower extremity muscles. As Bell et al (2000) postulated, these strength loss mechanisms may have become operational in a much shorter time period due to the continuous catabolic conditions and high level of endurance demands over the 8-week basic training period.

On the other hand, maximal isometric leg and arm extension force improved both in the ST and ET groups but not in the NT group. The overall training loads during BT in NT were not a sufficient stimulus to increase maximal strength of the lower extremities. The small but statistically significant increase in maximal strength of the arm extensors observed in ET might be in part result from the fact that a part of the endurance training was performed by the Nordic walking as a training method, which is known to load the upper extremity muscles. This exercise may thus have increased neural activation of the arm extensors in the ET group. However, it should be noted that bench press is a multi-muscle action, which activates also the pectoralis and deltoid muscles in addition to upper arm extensors. Military activities, in general, contain a lot of activities like lifting or carrying heavy materials, which enhances power of the upper extremities.

Lower levels of physical activity before military service was associated with higher improvements in isometric force of the bilateral leg extension and in arm extension during BT. In addition, the difference in isometric force between the active and inactive subjects was reduced significantly compared to the initial values. The role of training is important in military actions; therefore, optimal training programs could enhance soldier's physical performance before operational stress while at the same time could help prevent the damaging effects of hard military training on physical performance.

In summary, the present BT programme in the Finnish Defence Forces with added strength and endurance training significantly improved maximal strength in the upper and lower extremities of the conscripts. In addition, subjects with lower physical activity had the greatest improvements in strength development. However, none of the training groups showed increases in the muscle thickness of the measured muscles. BT, including a large amount of endurance based military training, may cause some interference with strength development and explosive power output of the lower extremities in the ST group, but ST did increase their explosive strength in the upper extremities.

6.3 Hormonal adaptations to added endurance and strength training (study II, paper IV)

The 8-week basic training period combined with added sport-related ST or ET significantly increased serum basal testosterone (TES) concentration levels. In addition, significant increases were observed in serum basal cortisol (COR) concentration levels in the ST group, while no increases were observed in the NT and ET groups. However, no associations were recorded between VO_2max values and baseline TES or COR concentrations. Furthermore, significant increases in the TES/COR ratio were recorded in the NT and ET groups, while no change was observed in ST. All training groups increased their serum TES/SHBG ratio.

Elevations in basal TES concentration during the 8-week basic training period may indicate that the present BT training frequency, volume and intensity have been adequate to create positive training responses all training groups. On the other hand, unexpectedly low strength gains in the ST group may be the consequence of a total training frequency and volume that was too high. Alternatively, Kraemer and Ratamess (2005) have reviewed that the frequency of 2–3 strength training days per week is an effective initial frequency for untrained individuals. This was also the case in the present ST group, where they had three strength training sessions a week, and where most of the subjects did not have earlier systematic strength training experience. Increased basal serum COR concentration and lower TES/COR ratio may have minimized strength gains and possibly muscle hypertrophy in the ST group due to some overreaching or interference effect induced by a concomitant high amount of endurance-based military training. Furthermore, statistically higher increases in the basal TES concentration in the NT and ET groups may partly explain their increases in aerobic and muscle strength performance.

Nindl et al (2007) have earlier reported that the increase in COR may have reproduced lipolysis and degradation of muscle protein synthesis. It has also been demonstrated that concurrent endurance and strength training, which alters the balance between anabolic and catabolic hormones, may reduce fibre hypertrophy and consequently strength development (Almon and Dubois 1990). Serum testosterone and cortisol, or their ratios, have been used as markers of muscle anabolism and catabolism. High volume concurrent training has been shown to be associated with an increase in serum COR levels (Kraemer et al. 1995) as might have occurred in the present study. A significant correlation was observed between initial TES levels and the changes of TES concentration levels after the 8-week basic training season. Those subjects who had lower initial levels of serum TES in the beginning of BT demonstrated larger increases in their concentrations compared to subjects with higher initial TES levels. Thus, large interindividual variance in the changes of serum TES were observed. However, these changes in TES concentrations were not related to changes in strength or endurance performance over the 8-week training period.

The subjects with higher previous physical activity, over a period of 3 months before the military service, seem to have higher increases in basal TES levels. The general training load of the BT season might be too high for the inactive subjects. Therefore, some individualization of sport-related training programmes combined with military training may be required. However, in the present study, optimal and specific responses of aerobic capacity and muscle strength development of the conscripts induced by the ST and ET programmes were most likely interfered with a high amount of endurance based military training.

In the present study, serum basal T4 concentration decreased significantly during the 8-week training period in all training groups. This may be a consequence of the imbalance between energy intake and energy expenditure, while no hypertrophic training effects were recorded, and significant decreases in BF were observed after the 8-week training in all subject groups. In addition, the lack of relationship between maximal strength development and muscle hypertrophy after a prolonged training period is supported by earlier findings, when serum thyroid hormone levels have shown to decrease during long lasting military training or exercises with low energy intake and high energy expenditure (Friedl et al. 2000, Kyröläinen et al. 2008, Nindl et al. 2007) causing significant decreases in body fat and in lean body mass. Friedl et al (1997) have suggested that nearly all field-training investigations examining energy balance have demonstrated inadequate energy intakes. A review of 19 study groups and 11 different reports (Jones et al. 1990) has demonstrated average energy expenditures of 3670 ± 680 kcal per day, but intakes averaging only 2510 ± 440 kcal. Body weight loss averaged 2.4 ± 1.1 kg over the course of the field studies, which were usually 10 days in duration. Gomes-Merino et al (2003) and Kyröläinen et al (2008) have later reported that energy expenditure could exceed to 5000 kcal or over that a day during the military field exercises. In our study, the subjects daily energy intake were approximately 3000 kcal served by the garrison dining hall and during the field exercises more than 3500 kcal (Kyröläinen et al. 2008) which might be inadequate for optimal training responses. Opstad (1995) has also suggested that the degradation of the thyroid hormone concentration during a 5-day military field exercise were due to prolonged physical stress and low calorie intake. A limitation in our study was a lack of measurements on energy expenditure. Therefore, the role of the possible energy deficit remained unclear.

In summary, significant increases were observed in serum basal TES concentration indicating that the training frequency, volume and intensity have been adequate to create positive training responses in all groups. Increases in serum basal COR concentrations and limited strength development and minor muscle hypertrophy in the ST group might be a consequence of too high of an amount of endurance-based military training. High energy expenditure during the 8-week training season and possible energy deficit also may have led to decreases in serum basal T4 concentration contributing to the degree of muscle protein synthesis.

6.4 Physiological responses during the field running test (study III, paper V)

The present 8-week basic training study demonstrated that the combined sport related physical training (SRPT) with added strength or endurance training (3 times a week) significantly improved a novel 3 K field running performance in the ST and ET groups. However, no differences in the training adaptations were noticed between the experimental groups and the NT group. This could be due to initial incompatibility of the demands of the BT period with additional specific exercise training or a redundancy of aerobic stimuli as post-training 3K combat run times were all similar (Hickson 1980). It can be further speculated that the demands of the 8-week BT reduced the expected magnitude of muscular strength adaptations induced by a periodized strength training programs (Hickson 1980).

It has been earlier demonstrated that concurrent endurance and strength training is an important and maybe even an essential training method needed to achieve optimal improvements in demanding military task-related performance, especially, in a load carriage performance (Kraemer et al. 2004). Kraemer et al (1995, 2004) have shown that only groups performing concurrent training significantly decreased their run times despite other variables like type I muscle fiber growth, anaerobic power were found to interfere with such simultaneous training (Kraemer et al. 1995). Interestingly, the groups that did just strength or endurance training programs did not see any real improvements in the load carriage task after 3 months of training 4 times per week.

In the present study, the NT group, which participated in the normal basic training program, similarly improved their time in 3K loaded combat running performance as did the ST and ET groups. This indicates that for this military relevant task, the training stimulus provided by the NT program was adequate. The addition of more strength training or more aerobic training did not appear to contribute to improvements in this military relevant task. This might be partly due to the lower load being carried by the soldiers in this test. Alternatively, it is possible that the challenging demands of the basic training course itself obviated then needed short term training adaptations that would be able to contribute to a faster pace in the test. It is unclear whether more individualized training programs might have yielded different results. In the current study, the additive effect on the military relevant task of a 3K loaded combat run test was not observed and the aerobic stimuli needed for this improvement could be achieved by 15-20% lower amount of endurance training as it was a case in the ST group. These improvements may be a consequence of improved maximal oxygen uptake and partly by improved maximal force production of the lower body extremities in a relation to better running economy. Earlier, Kyröläinen et al (2000) have suggested that higher or strengthened neuromuscular functions may effect on running economy due to lower muscle damage in subjects with higher muscle strength levels during the demanding running performance. Furthermore, the 3K loaded combat running test caused minor responses to the hand grip force, while soldiers carried their rifles with a sling. This may indicate lower muscle activation in arm extensors during the field running test.

In the present study, the initial VO_2max level was the main determinant of the improved field running performance. This is partly in line with the findings of Rosendahl et al (2003), who reported that a 12-week military training course led to significant improvements in running test times and in VO_2max values in untrained soldiers but not in the well-trained soldiers. However, in the study by Kraemer et al (1995) even the highly trained soldiers not involved with any basic or advanced course all improved in their treadmill VO_2max values even if they were concurrently strength training. This demonstrates that strength training does not interfere with aerobic improvements.

In the latter part of the 3K loaded combat run test, average heart rate was significantly higher in all subject groups when compared to pre-training testing This clearly indicates that the soldier's field running performance and aerobic capacity has significantly improved allowing a greater cardiovascular output in order to achieve a faster run time by the end of the 8-week basic training program. Such data indicates that while the performance times were faster, the expected cardiovascular vagal tone achieved over the 8 week basic training course was not observed. The lack of a decided advantage in the ET group to perform better in the 3K loaded combat running test shows that some type of interference of the basic training course with a specific endurance training program employed in this study. This may well be due to all of the additional physical and psychological demands of a challenging basic training course in young men who are unaccustomed to physical training and the military. Yet greater toleration of the cardiovascular strain was achieved in all groups allowing for enhanced performance. This finding of incompatibility in the early weeks of a basic training and endurance training program is a novel finding and has not previously been shown in the scientific literature in military physiology.

In the present study, the higher initial levels of maximal isometric force production of leg extensors were associated with faster 3K loaded combat running test times in the before after training comparison. Again, strength training three times a week did not lead to interference with the development of running performance which is in line with prior studies (Bell et al. 2000, Kraemer et al. 1995). However, Bell et al (2000) did caution that long term concurrent training may lead to an elevated catabolic state, decreased skeletal muscle hypertrophy which may in turn impair the magnitude of strength gains.

The acute exercise induced hormonal responses observed in the present study are consistent with earlier findings of Galbo (1981), Bunt et al (1986) and Kraemer et al (1995, 1998), since significant increases were demonstrated in acute serum responses of GH, TES and COR. The hormonal changes during the 8-week resistance training study by Kraemer et al (1998) in untrained young men, in comparison to the responses and adaptations observed in the current study, may demonstrate the impact of the addition of basic training to a strength training program. In Kraemer's study, TES, COR and GH all increased in response to an acute resistance exercise stress. Different from the current study is that the men increased their resting total TES after 6 weeks of training and reduced their resting COR after 8 weeks of training. However, they saw no changes in the GH response to exercise or with training. In comparison, while exercise induced increases were observed in GH in all of the groups in Kraemer's study, the present study demonstrated a significant post-training increases in serum GH responses to acute 3K loaded combat run in the ST and ET groups.

In summary, significant improvements were observed in novel 3K loaded combat running test times in all training groups after an the 8-week military basic training course. However, the magnitude of training specific gains from an endurance training program added to the ET group and a periodized strength training program added to the ST group was interfered due to other endurance based military training. This indicates an interference with the normal physiological adaptations that are associated with endurance and strength training, which can be seen as minor specified adaptations in the experimental groups. The NT group saw similar`, if not identical, adaptations to the tests conducted. The mechanisms for these responses remain speculative but could be based in the high levels of endurance demands in the BT course augmented by the psychological demands of military training. Thus, it seems that some individualized training program, based on initial physical fitness, is needed to achieve more specific training responses.

6.5 Limitations of studies I - III

This brief section will outline the main limitations of the study, though several other smaller limitations also exist. The results of study I consisted of quite a unique population-based data regarding the physical fitness profiles of 20-year old young men. Unfortunately, it was not possible to add standard deviations to the reported means. The present retrospective data of study did not allow us to use individual values, because the data had been collected as garrison or unit means. Nevertheless, the present data is valuable to report.

In spite of positive training responses during this investigation, the design of our study had some limitations. In study II-III the missing independent control group can be regarded as a limitation. In addition, there was a lack of measurements with regard to energy expenditure. Therefore, the role of the possible energy deficit remained unclear. Another weakness of the present investigation was that the study protocol did not have any measurements to record acute hormone responses to different training bouts. This might be an important issue for future investigations. The ultrasound measurements are also known to have a lower accuracy in the muscle thickness measurements compared to those of MRI or CT devises used for muscle thickness or cross-sectional measures. The bicycle ergometer test was chosen as an aerobic performance test due to the practical reasons instead of the traditional and more accuracy treadmill run, while all the tests were implemented in the garrison area and transferrable treadmills were not available for the this study.

In addition, in the present study only two basal serum hormonal measurements was performed during the 8-week training period, which did not enable the detailed examination of the time course of hormonal responses throughout the 8-week period. Possible psychosocial stress effects on the training responses and basal serum hormone concentrations were not taken into account. Finally, it might be possible that the training programmes of the present study did not differ sufficiently with regard to a total training load and volume. In addition, free-time physical activity of the subjects was not controlled during the intervention.

7 PRIMARY FINDINGS AND CONCLUSIONS

The main findings and conclusions of the present studies can be summarised as follows:

1) The present study I (paper I) revealed that aerobic fitness and muscle endurance of young 20 year old men has decreased and body mass has increased during the last 15 years in Finland. It is important to note that these negative phenomena may cause serious health problems among the whole population in the future. In addition, weakened physical fitness levels of young men have to be taken into consideration when developing optimal military training programmes.

2) The current basic training programme of the Finnish Defence Forces, including a high amount of endurance training, like sport related physical training, combat and march training caused significant improvements in the cardiovascular performance of the conscripts (paper II). On the other hand, no further improvements in VO_2max were obtained by specific endurance training 3 times a week. In addition, the special strength training programme 3 times a week combined with BT positively enhanced the aerobic capacity of the conscripts, and did not lead to interference with the development of VO_2max.

3) The present basic training programme with added strength and endurance training caused significant improvements in maximal strength of the upper and lower body extremities in the conscripts (original paper III). In addition, BT positively influenced body composition by decreasing body fat and waist circumference in all groups, while none of the groups showed increases in the muscle thickness of measured muscles. These findings may also partly be explained by some imbalance between energy expenditure and energy intake. Possible energy deficit and the large amount of military based endurance training may have facilitated aerobic metabolism and inhibited protein synthesis leading to somewhat lower strength development and explosive power output in the ST group as one could expect (paper IV).

4) The 8-week basic training programme with added endurance and strength training induced the greatest improvements in the VO_2max values of the inactive subjects (paper II). In addition, the difference in the VO_2max values between the active and inactive subjects was reduced significantly compared to the initial values. Thus, inactive subjects obtained almost the same fitness level as active subjects during the 8-week training period. It was also quite useful, for practical purposes, to note that subjects who performed low levels of physical activity had the highest improvements in their aerobic capacity and maximal strength development (paper II and III). To obtain more individualized training responses, it may be essential that the soldiers that already have a high VO_2max receive more high intensity endurance training or otherwise more demanding military training. On the other hand, soldiers with high VO_2max may also need more strength training in their training program and soldiers with lower VO_2max may need more endurance training, when combined endurance and strength training is undertaken.

5) The present study II (paper III) suggests that strength training is be an important part of the training program during the BT season. However, it seems that the ST programme combined with military training might require some decreases in the amount of the endurance based military training and/or some increases in the volume of the maximal/explosive strength training. To what extent the amount and type of strength training should be modified for optimal strength and power development needs further investigations. Moreover, some individualization of strength training programmes combined with military training may also be required.

6) The present 8-week basic training study II (paper IV) with added endurance and strength training induced significant increases in serum basal TES concentration in all groups indicating that the training frequency, volume and intensity were adequate in creating a positive training response. However, increases in serum basal COR concentrations and limited strength development and minor muscle hypertrophy in the ST group might be a consequence of too high of a volume of endurance-based military training.

7) The 8-week basic training programme with added endurance and strength training induced significant improvements in the times of a novel 3K loaded combat running test in all training groups (paper V). However, the magnitude of training-specific gains from an endurance training program added to the ET group and a periodized strength training program added to the ST group was blunted by the challenges and demands of the basic training alone as few differences existed among the three groups.

8) The primary findings of studies II and III also demonstrated that the demands of the 8-week BT period muted the optimal training adaptations of specific strength or endurance training in the conscripts' aerobic fitness, upper and lower body muscle strength development, and field running performance.

In addition, all training groups demonstrated a similar level of improved performance. Therefore, a reduction in the volume of endurance training activities in a basic training program within more focused concurrent strength and endurance training programs might allow for more optimal training for combat readiness in advanced courses or mission operational environments. To what extent improvements in endurance and strength performance can be obtained throughout the entire duration of military service needs further experimental research work. Furthermore, monitoring of the changes or lack thereof in various physical fitness parameters may be warranted to minimize possible overtraining.

YHTEENVETO (Finnish Summary)

Lisätyn voima- ja kestävyysharjoittelun vaikutukset varusmiesten hengitys- ja verenkiertoelimistön sekä hermo-lihasjärjestelmän suorituskykyyn kahdeksan viikon peruskoulutuskauden aikana

Tämän tutkimuksen tarkoituksena oli aluksi selvittää millaisia muutoksia on tapahtunut palvelukseen astuvien suomalaisten varusmiesten kehon koostumuksessa, aerobisessa suorituskyvyssä sekä lihaskunnossa viimeisen kolmen vuosikymmenen aikana. Lisäksi tutkimuksen toisena päätarkoituksena oli selvittää lisätyn voima- tai kestävyysharjoittelun vaikutuksia varusmiesten hengitys- ja verenkierto-elimistön sekä hermo-lihasjärjestelmän suorituskykyyn ja maastojuoksusuorituskykyyn taisteluvarustuksessa kahdeksan viikon peruskoulutuskauden aikana.

Tutkimustulokset osoittivat, että palvelukseen astuvien noin 20 vuotiaiden suomalaisten varusmiesten aerobinen suorituskyky ja lihaskunto ovat laskeneet viimeisen kahdenkymmenen vuoden aikana ja vastaavasti heidän kehonsa keskipaino on noussut viimeisen 15 vuoden aikana. Fyysisen suorituskyvyn lasku ja kehonpainon nousu ovat eittämättä uhka suomalaisten miesten kansanterveydelle. Vallitseva tilanne aiheuttaa myös lisääntyviä muutospaineita Suomen puolustusvoimien koulutusjärjestelmän kehittämiselle etenkin fyysisen koulutuksen ja liikuntakoulutuksen osalta.

Tämän tutkimuksen varsinaisessa harjoitteluinterventiossa havaittiin, että Suomen puolustusvoimien voimassa oleva peruskoulutuskauden koulutusohjelma paransi merkitsevästi varusmiesten maksimaalista hapenottokykyä, maastojuoksusuorituskykyä sekä ylä- että alavartalon maksimaalista voimantuottoa. Seerumin testosteronitaso nousi peruskoulutuskaudella kaikilla harjoitusryhmillä indikoiden osaltaan, että eri tutkimusryhmien harjoittelumäärä, harjoitusvolyymi sekä harjoitusteho olivat olleet riittäviä positiivisten kuntomuutosten aikaansaamiseksi. Lisätty voimaharjoittelu yhdistettynä nykyiseen peruskoulutuskauden koulutukseen johti kuitenkin voimaharjoitteluryhmän varusmiesten seerumin kortisolipitoisuuden nousuun. Voimaharjoitteluryhmän maksimivoimatasojen muutokset sekä lihaksen poikkipinta-alan kasvu eivät poikenneet tilastollisesti merkitsevästi muista harjoitteluryhmistä.

Peruskoulutuskauden harjoittelu pienensi myös varusmiesten kehon rasvaprosenttia ja vyötärön ympärystä kaikissa harjoitteluryhmissä. Kunnon nousu ja kehon koostumuksen muutokset olivat sitä myönteisemmät, mitä huonommassa kunnossa varusmiehet olivat palveluksen alussa olleet, ja mitä alhaisempi oli heidän palvelusta edeltävä liikunta-aktiivisuus.

Tämän tutkimuksen perusteella voidaan olettaa, että peruskoulutuskauden liian runsas kestävyyspainotteinen sotilaskoulutus saattoi osittain estää voima- sekä kestävyysharjoittelun tyypilliset spesifiset vaikutukset. Voimaharjoitteluun painottuneen ryhmän maksimivoimamuutokset olivat odotettua pienemmät ja eri harjoitteluryhmien väliset muutosten erot olivat lähes kaikissa mittauksissa suhteellisen pieniä. Voimaharjoittelu kolme kertaa viikossa ei kuitenkaan estänyt varusmiesten maksimaalisen hapenottokyvyn kehittymistä. Myöskään kestävyysharjoitteluun painottuneen ryhmän maksimaalinen hapenottokyky ei lisääntynyt muita ryhmiä enemmän kolme kertaa viikossa tapahtuneella kestävyysharjoittelulla.

Tämä tutkimus on osoittanut, että voimaharjoittelu on tärkeä ja jopa välttämätön osa peruskoulutuskauden ohjelmaa, koska kestävyysharjoittelua lisäämällä ei saavuteta merkittäviä lisähyötyjä varusmiesten fyysiselle suorituskyvylle. Voimaharjoittelulla tiedetään olevan myönteinen vaikutus sotilaiden usein kantaman lisäkuorman kantokykyyn ja vammautumisen ennaltaehkäisyyn. Voimaharjoittelun spesifisten vaikutusten lisäämiseksi tulisi peruskoulutuskauden kestävyyspainotteista sotilaskoulutuksen määrä vähentää ja voimaharjoittelun osuutta lisätä. Tämän lisäksi tarvitaan yksilöllisempiä voima- ja kestävyysharjoitusohjelmia, jotka perustuvat palvelukseen astuvien varusmiesten lähtökuntotasoihin sekä heidän fyysisissä perusominaisuuksissa ilmeneviin puutteisiin.

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