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Effects of military basic training on VO_{2max}, body composition, muscle strength and neural responses in conscripts of different aerobic condition

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Summary

Study aim: The purpose of this study was to evaluate neuromuscular adaptations in conscripts with different fitness levels (VO_{2max}) during 8 weeks of military basic training (BT).
Material and methods: Twenty-four male conscripts (18–21 years) were divided into two groups (Good Fitness [GF] and Low fitness [LF]) based on their VO_{2max} at the beginning of BT. Body mass (BM), fat free mass (FFM) and Fat% were measured after 2, 4, and 7 weeks of training. VO_{2max}, maximal isometric leg press force (MVC), H-reflex (H_{max}/M_{max}) at rest and V-wave (V/M_{max}) during maximal isometric plantarflexion were measured from the soleus muscle at the beginning, after 5, and after 8 weeks of training.
Results: FFM decreased significantly in LF after 7 weeks of training (–3.0 ± 1.7%, $p < 0.001$), which was not observed in GF. Both GF (6.9 ± 4.6%, $p < 0.01$) and LF (5.7 ± 4.6%, $p < 0.01$) showed improved VO_{2max} after 5 weeks, with no changes during the last 3 weeks. A main effect of training was observed in decreased leg press MVC (–7.3 ± 9.3%, F = 4.899, $p < 0.05$), with no between-group differences. V-wave was significantly lower in LF during 5 (–37.9%, $p < 0.05$) and 8 (–44.9%, $p < 0.05$) weeks.
Conclusion: Poor development of the neuromuscular system during BT suggests that explosive and/or maximal strength training should be added to the BT protocol for all conscripts regardless of fitness level. In addition, individualized training periodization should be considered to optimize the training load.

Keywords: Aerobic fitness – Neuromuscular adaptation – Military training

Introduction

It has previously been shown that physical fitness of the younger population has decreased during the past decades while their body mass has increased significantly [10, 11, 26]. For conscripts of poor physical condition, the basic training (BT) period may be too strenuous and possibly lead to musculoskeletal injuries and drop outs. On the other hand, for high fitness conscripts training may be insufficient, thus leading to poor physical development. The main purpose of military BT is to prepare conscripts both physically and mentally for specialized military training. Furthermore, it aims to improve soldiers' aerobic fitness and neuromuscular performance so that conscripts are able to cope with demanding military tasks [24].

Aerobic and strength capacity can be improved with endurance and strength training; however, neuromuscular adaptation to these training types differs. An explosive and/or maximal strength training regimen can improve neural activity and 3–5 weeks of training has been shown to improve strength capacity [17]. In endurance training, aerobic fitness will generally only be accompanied by minor improvements in strength capacity [4]. In addition to changes in muscle performance, motor control adaptations at spinal and supraspinal levels may also have significant training type related differences. The Hoffmann-reflex (H-reflex) method has been used as an indicator of spinal level excitability [18]. However, the H-reflex response is highly influenced by other sources such as excitability of the muscle spindle, inhibitory activation from the Ib afferents, inhibitory sources in motoneuron level (recurrent inhibition) and especially presynaptic inhibition [16].

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Therefore the H-reflex is more like the oligo-synaptic than the monosynaptic response. Because H-reflex measures mostly slow-twitch muscle fibres [3], it seems to be higher in endurance than strength trained athletes [12].

A V-wave response, which is an electrophysiological variation of the H-reflex [31], is measured during maximal force production. It indicates neural drive activity from the supraspinal sources, although changes in spinal level activity may also have effects on it. It has been shown during both long [1] and short [32] training periods that heavy resistance training will increase V-wave responses, with minor or no changes in the H-reflex response, showing improvements in supraspinal activation. Thus, neural adaptation is highly dependent on the type of training. However, combining these training forms may lead to improvements in both endurance and strength performances. Several studies have recently shown that it is possible to improve muscular strength and power by combining endurance and strength training without losing aerobic fitness [14, 15]. This is also true in the military environment, where it has been reported that the addition of strength training during the BT period did not interfere with the development of improved aerobic fitness [24, 25]. Despite the background or physical fitness of the individuals, the training load during military training is quite similar for all conscripts, which may lead to different training adaptations.

To the best of our knowledge, no previous studies have examined the effects of military BT on neuromuscular function in conscripts with different levels of maximal aerobic fitness (VO_{2max}). In general, a high amount of aerobic training [33] during BT might lead to minor development in neuromuscular performance. On the other hand, in low fitness level conscripts, BT may be too strenuous, which may even result in a decrease in their neuromuscular performance. Therefore, the purpose of the present study was to evaluate neuromuscular adaptations and their relationship to VO_{2max} during 8 weeks of BT. VO_{2max} was also used to divide subjects into different fitness groups and to evaluate aerobic adaptations during BT. Force production was measured during maximal isometric leg press. Neural adaptations were measured using H-reflex (spinal) and V-wave (supraspinal) tests, which were measured from the soleus muscle. In addition, body composition was measured to analyze possible anthropometric adaptations. All methods have been described in more detail in the methods. It was hypothesized that force production would not be improved because of the high amount of endurance training included in BT. This should also be observed in unaltered V-wave responses indicating a lack of supraspinal activity improvements. Spinal level excitability (H-reflex) may be improved due to endurance-oriented training.

Materials and methods

Subjects

Twenty-four healthy male conscripts (18–21 years) participated in the study. They were divided into two groups (Good Fitness; GF, N = 12, body mass 68 ± 7 kg, height 1.74 ± 0.09 m and Low Fitness; LF, N = 12, body mass 88 ± 17 kg, height 1.80 + 0.08 m) based on their VO_{2max} values at the beginning of BT as follows: Good Fitness >45.0 (59–45) ml/kg/min and Low Fitness <45.0 (44–29) ml/kg/min (Fig. 1). The level of 45 ml/kg/min was

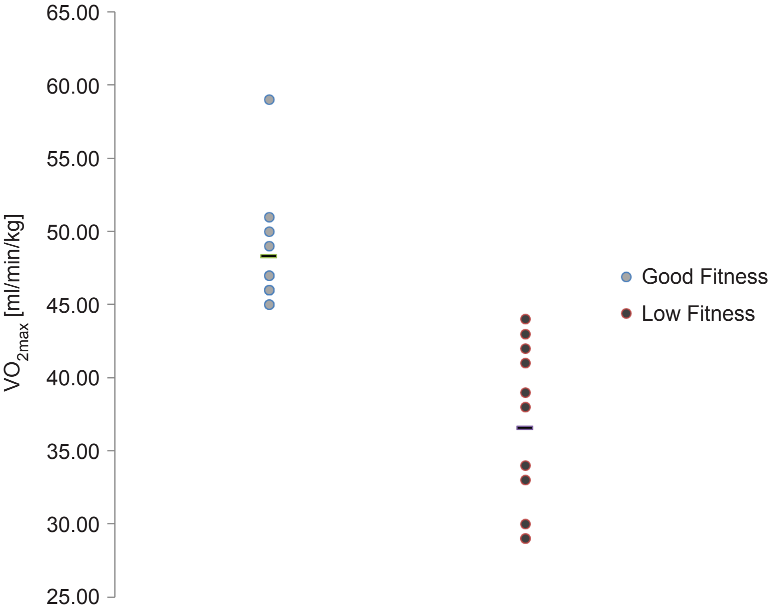

Fig. 1. Individual maximal oxygen uptakes (ml/min/kg) at the beginning of BT (thick line indicates mean value of groups)

chosen to divide subjects equally into good fitness (superior, excellent, good) and low fitness (fair, poor, very poor) groups [27]. All subjects were informed and fully aware of the experimental protocol and possible risks and they gave their written consent to participate in the study. The conscripts participating in this study were a part of a larger group of conscripts described previously [28–30]. They were randomly selected in the present study. The study was conducted according to the Declaration of Helsinki, and it was approved by the Finnish Defence Forces and the Ethical Committees of the University of Jyväskylä and the Kainuu Region of Finland.

Basic training period

The basic training (BT) period lasted 8 weeks, and was conducted according to the general physical training guidelines of the Finnish Defence Forces. All conscripts used the same military training schedule throughout the BT period. The intensity level of day-to-day physical activity was low during the first week but thereafter it increased. Military training consisted of heavy physical activities such as marches, battle drills, and other types of physical sport exercises. In addition, conscripts carried heavy combat training equipment of 15–25 kg as part of their exercises, especially during marches and combat training. The training period also included field exercises done overnight. Along with physical exercises, throughout the eight weeks there were theoretical studies taught in the garrison classroom, materials handling, shooting, gun handling, and general military training, such as closed marching exercises during the BT period. Besides the guided exercises, conscripts were marching four times a day to their eating place (~350 meters in one direction), which increased the total amount of marching up to 5–7 km each day of BT. The BT period also included 4 longer (2–8 hours) marching exercises while carrying heavy combat training equipment, daily outdoor exercises, as well as transitions between venues frequently performed by marching, which increased the amount of endurance activity significantly throughout the training period [24, 25]. Tanskanen et al. [29] reported that in the beginning of the BT the duration of training was approximately 2 hours and 21 minutes per day, increasing to 3–4 hours per day during BT weeks 4–7.

Measurements

Aerobic fitness and neuromuscular measurements were performed at the beginning (1 week), in the middle (5 weeks) and at the end (8 weeks) of BT. The protocol consisted of a maximal aerobic fitness test (VO_{2max}) and neuromuscular measurements (maximal isometric leg press force [MVC], H-reflex and V-wave). Body composition was also measured at the beginning (2 weeks), in the middle (4 weeks) and at the end (7 weeks) of BT. Subject were familiarized with all measurements before the tests. The experimental protocol is presented in Table 1 and all methods are described in more detail in the methods section.

Body composition

Body composition measurements (body mass [BM], fat free mass [FFM], and percentage of body fat [F%]) were performed at the same time points as the marching tests using 8-point bioelectrical impedance (Inbody720, Biospace Co. Ltd, Seoul, Korea) [2]. For each subject, the measurements were performed at the same time between 6 a.m. and 7 a.m. after an overnight fast and after voiding, with no exercise for 12 hours before the test. The physical activities in the daily programme were planned to be of a low intensity on the day preceding each measurement and fluid status was estimated to be in balance based on the dietary records of the subjects. The subjects were barefoot and wore similar T-shirts and trousers (weight ~200 g) in each measurement. Body height was measured to the nearest 0.5 cm using a wall-mounted stadiometer.

Maximal leg press force (MVC)

MVC was measured from both legs with a leg press (leg extension) dynamometer (University of Jyväskylä, Finland) [9]. The subjects were seated on the bench with 100 deg hip and 107 deg knee angles, keeping their hands on their chest. Firstly, they did a warm-up of 15 submaximal voluntary contractions. After a 1-minute rest, they performed 3 maximal voluntary contractions at a duration of 2–3 s and with 1 min of seated rest between the performances. Force production was simultaneously recorded from both legs with a strain-gauge force transducer. The measured signals were amplified and transferred through

Table 1. Experimental design during the 8-week military basic training period

Week	1	2	3	4	5	6	7	8
VO_{2max} test	X				X			X
Force* and neuromuscular measurements **	X				X			X
Body composition		X		X			X	

* Maximal isometric leg press force (MVC) and rate of force development (RFD); ** H-reflex and V-wave.

an isolation unit (ME4ISO, MegaElectronics Ltd., Finland) and measuring unit (ME6000, Mega Electronics Ltd., Finland) to the MegaWin software (Mega Electronics Ltd., Finland) for later analysis. The best performance according to MVC was selected for further analyses.

Electromyography

Electromyographic activity was recorded from the soleus and muscle using bipolar (20-mm distance) surface electrodes. The electrode was placed according to SENIAM [6] guidelines. The EMG signals were measured (15-500 Hz passband, sampling rate 1000 Hz, gain 1000) and recorded using a wireless connection (MegaWin software, biomonitor ME6000; Mega Electronics Ltd, Finland).

H-reflex

H-reflex at rest was measured in a standing position from the soleus muscle [20]. Measurement was done using a fixed bipolar electrode with an anode placed over the patella and cathode over the tibial nerve. The correct position of the fixed electrode was determined with a movable stimulation electrode by analysing the shape of the EMG waves at different stimulation intensities with a criterion of peak-to-peak amplitude being the only parameter changing. A supramaximal stimulus (with 0.2 ms duration at ca. 0.2 Hz stimulation frequency) was given to the tibial nerve with a stimulator (DS7A, Digimeter Ltd, Welwyn Garden City, England) and the EMG measurements were collected from the soleus muscle. Maximal M-wave (M_{max}), maximal H-reflex (H_{max}) responses and H_{max}/M_{max} ratio were analysed from the averaged results to evaluate the sensitivity of the α-motoneuron pool and/or synaptic transmission efficiency at the spinal level.

V-wave

V-wave response was measured from the soleus muscle with H-reflex recordings while doing a maximal isometric plantarflexion at the hip angle of 110 deg, knee angle 180 deg, and ankle angle 90 deg [20]. This knee angle was used to ensure that the subject was mainly using the soleus muscle during the movement. The subject did 5 maximal plantarflexion repetitions with one min intervals. A supramaximal stimulus was given to the tibial nerve after one second from the start of the contraction. Maximal M-wave, V-wave and V/M_{max} ratio were analysed after calculating their average measures.

VO_{2max}

Each subject performed the test at the same time of day, between 8:30 a.m. and 5:00 p.m., after consumption of a similar diet at the same time of day before each test. The test started with a warm up of 3 minutes of walking at 4.6 km/h, which was followed by walking or jogging at 6.3 km/h (1 degree slope). After the warm up, the exercise intensity was increased every three minutes to induce an increase of 6 ml/kg/min in the theoretical VO_{2max} demand of running [23]. The initial running speed was increased by a mean of 1.2 km/h (range 0.6–1.4 km/h), and the initial slope (1 deg) was increased by a mean grade of 0.5 deg (range 0.0–1.0 deg) every three minutes. The test was continued until exhaustion. The collected data considered heart rate (Polar810i; Polar Electro Oy, Kempele, Finland), pulmonary ventilation and respiratory gas exchange using the breath-by-breath method (Jaeger Oxygen Pro; Viasys Healthcare GmbH, Hoechberg, Germany). The mean values were calculated from the measured results at 1 minute intervals for later statistical analysis. The criteria used for determining VO_{2max} were: VO_{2max} and heart rate did not increase despite an increase in the exercise intensity, a respiratory exchange ratio (RER) higher than 1.1, and a post-exercise blood lactate (Lactate analyzer; LactatePro, Arkray, Japan) higher than 8 mmol/l (Roitman & Herridge, 2001). All participants satisfied these criteria [29].

Statistical analyses

Mean values and confidence interval (±95%CI) were calculated. Two-way repeated measures ANOVA (LSD post hoc) was used to assess the main effects (training; within subjects effects) of measurement interval (VO_{2max}, and neuromuscular performance 1, 5 and 8 weeks, body composition 2, 4 and 7 weeks), fitness (group; between subjects effects) (Good Fitness, Poor Fitness) and interaction (training x group). Box's and Levene's tests were used to identify normal distribution and if normality was not observed, log-transformed values were used. Mauchly's test of sphericity was used to test the assumption of sphericity. Where this assumption was violated, Greenhouse-Geisser adjustments were used. Where significant main effects or interactions were observed, pairwise comparisons were used to identify the location of differences between measurement intervals and training status. Results were considered statistically significant for p-values below 0.05. Data were analyzed using PASW software version 18.0 (SPSS Inc., Chicago, IL, USA).

Results

Body composition

At the beginning of BT, significant main effects and interaction were observed in body mass (training; $F = 24.657$, $p < 0.001$, group; $F = 11.325$, $p < 0.01$, training x group; $F = 11.967$, $p < 0.01$,) and FFM (training; $F = 8.879$, $p < 0.01$, group; $F = 7.534$, $p < 0.05$, training x group; $F = 5.376$, $p < 0.05$). BT induced a decrease in body mass (–5.4 ± 1.5%, $p < 0.001$) and fat free mass (–3.0 ± 1.0%, $p < 0.001$) in LF, which was not observed in GF (body

Table 2. Aerobic performance and body composition of the conscripts at the beginning, during and after 8 weeks of basic training mean ± (95%CI)

	GF			LF		
	1 week	4 week	8 week	1 week	4 week	8 week
VO_2max [ml/kg/min]	48 ± (2.4) ***	51 ± (2.2) *** ##	51 ± (2.2) ** #	36 ± (3.4)	41 ± (2.9) ###	42 ± (3.0) ###
	2 week	5 week	7 week	2 week	5 week	7 week
Body mass [kg]	68 ± (4.5) **	67 ± (4.6) **	67 ± (4.4) **	88 ± (10.1)	85 ± (9.9) ###	83 ± (9.1) ### ¤¤¤
FFM [kg]	57 ± (3.6) *	58 ± (3.9) *	57 ± (3.6) *	69 ± (5.7)	68 ± (6.0) ##	67 ± (5.3) #
Fat%	14 ± (2.5) **	13 ± (2.5) ** #	14 ± (2.1) *	21 ± (2.9)	19 ± (2.8) ##	19 ± (2.8) ##

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$ between GF and LF; # $p < 0.05$, ## $p < 0.01$, ### $p<0.001$ compared to 1 week; ¤ $p < 0.05$, ¤¤ $p < 0.01$, ¤¤¤ $p< 0.001$ compared to 5 weeks.

mass –1.2 ± 2.0%; fat free mass –0.3 ± 1.4%). At the end of BT, within group body mass ($p < 0.05$) and fat free mass ($p < 0.05$) were still significantly higher in LF than in GF ($p < 0.05$). In Fat%, no interaction was observed; however, significant main effects (training; $F = 12.980$, $p < 0.001$, group; $F = 9.440$, $p < 0.01$) were observed. In LF, Fat% decreased during the first 5 weeks (–6.3 ± 2.9%, $p < 0.01$) and in GF (–6.2 ± 5.6%, $p < 0.05$) (Table 2).

MVC

In MVC (Fig. 2), a significant main effect of training ($F = 4.899$, $p < 0.05$) was observed, but no interaction or between-group differences were observed.

H-reflex and V-wave

In H-reflex, no main effects (training or group) or interactions were observed during BT. However, in V-wave, a significant main effect of group ($F = 6.007$, $p < 0.05$) was observed (Fig. 3). In LF, normalized V-waves were significantly lower during weeks 5 (–37.9%, $p < 0.05$) and 8 (–44.9%, $p < 0.05$).

VO_{2MAX}

In VO_{2max}, significant main effects and an interaction were observed (training; $F = 42.770$, $p < 0.001$, group; $F = 23.230$, $p < 0.001$, training x group; $F = 6.760$, $p < 0.05$). Both groups improved their maximal aerobic

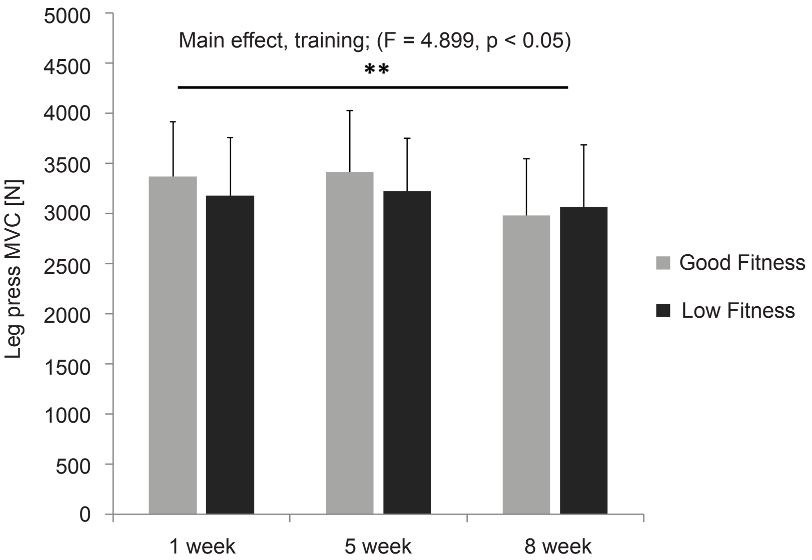

Fig. 2. Leg press MVC at the beginning, after 5 weeks and at the end of BT in the GF and LF conscripts. Significant main effect of training observed between the 1st and 8th week of training (mean, 95%CI)

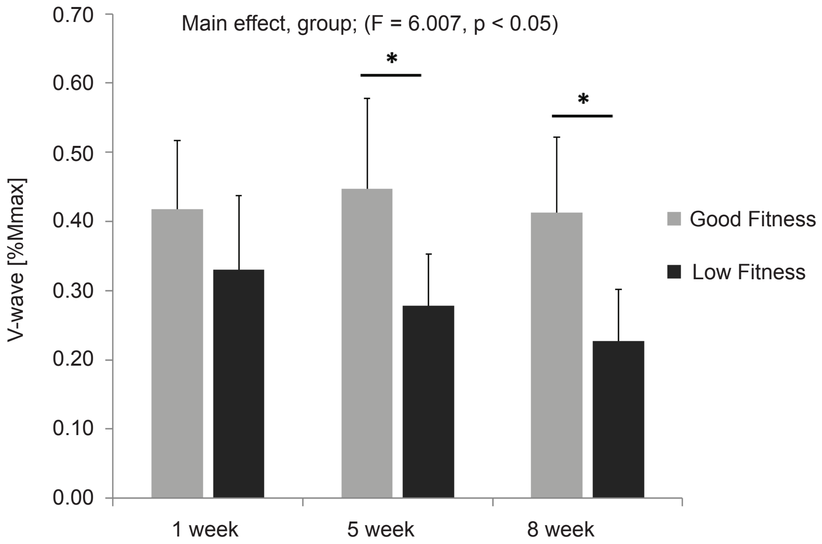

Fig. 3. Normalized maximum V-wave (Vmax/Mmax ratio) at the beginning, after 5 weeks and at the end of BT in the GF and LF conscripts. Significant between-group differences were observed during the 5th and 8th week of training (mean, 95%CI)

performance during the first 5 weeks (GF 6.9 ± 2.7%, $p < 0.01$; LF 16.7 ± 6.0%, $p < 0.01$), while changes were not observed between weeks 5 and 8 of BT (GF –0.8% ± 2.4%; LF 1.1% ± 2.5%) (Table 2).

Discussion

The main finding of the present study was that there were no between-group differences in neuromuscular adaptations, measured as neural responses (H-reflex and V-wave) and isometric leg press (MVC), among different aerobic fitness level conscripts during BT. These results confirm the suggestion that military BT is mostly endurance type training, which is further supported by the observed improvement in VO_{2max} within both groups during the first five weeks of BT. On the other hand, only LF lost both body mass and FFM during BT, which might thus be one major reason for poor neuromuscular development for the low fitness conscripts. Possible nutrition imbalance and/or overreaching in LF cannot be ruled out either. Development in force production is accompanied by increased voluntary neural activation and/or an increased muscle cross-sectional area due to hypertrophy of individual muscle fibres [5]. Thus, maximal leg press force was measured in the current study to evaluate the training adaptations during the BT period in the force production of the large leg muscles that are relevant e.g. for marching and in several combat situations. Interestingly, no between-group difference was observed in MVC during the training and MVC decreased regardless of the aerobic fitness level. One reason for insufficient strength development could be the high amount of endurance-based activity in the current military BT [8, 24]. Endurance training has previously been considered to interfere with explosive strength development by limiting the training induced changes in rapid neural activation [5]. More recently there have been several studies among endurance athletes [14, 15, 21] as well in untrained subjects [13] showing that endurance and strength training programmes can be combined without limitation of strength development. This may suggest that strength development in combined training may not be so strongly related to training history. Therefore, the explanation for poor force development seems to be a lack of strength training during BT, which is also supported by unchanged V-wave responses. V-wave measures neural drive from central sources and different forms of strength training have been shown to improve this response [1, 7, 32]. However, it should be mentioned that FFM was decreased in LF, which was not observed in GF. This could be an indicator of negative energy balance, which together with environmental changes and increased physical training leads to higher stress and poorer development of physical performance in prolonged military training [19].

H-reflex responses, which measure motor control at the spinal level, are shown to be dependent on training type. Based on an earlier study, athletes who participate in endurance training have a higher normalised H-reflex response [12], which may be caused by a higher percentage of slow twitch motor units [3]. However, a 1–2 month training period is an insufficient time period to see changes in muscle fibre types, so some neural adaptation, probably changes in presynaptic inhibition [32] or reciprocal inhibition, are more likely to be responsible for differences in the H-reflex response. In the present study, no changes were observed in spinal motor control in either of the groups. This may indicate that if some overreaching was present in LF (based on reduced FFM), they were not severely overtrained the end of BT. Raglin et al. [22]

observed decreased H-reflex responses in overtrained athletes, suggesting that severe fatigue or overtraining will also affect motor control at the spinal level.

Due to technical reasons H-reflex and V-wave were measured from different muscle groups than force production capabilities. Nevertheless, unchanged V-wave and H-reflex responses indicate poor neural adaptation from supraspinal and/or spinal sources. Previously, it has been shown that it is possible to improve neural drive during strength training [1, 32]. This result supports the suggestions that neural strength training (maximal and/or explosive) should be added at the beginning of BT [20, 25]. It should be pointed out that neural responses were similar in both groups and therefore added strength training should be a part of each conscript's physical training during BT. Previous studies have shown that added strength training during the BT period did not interfere with the development of aerobic fitness [24]. However, it is important to note that the optimal balance between different training responses should be found in a combined strength and endurance type training BT period to prevent overreaching for subjects especially with poor fitness level [5, 25]. It should also be mentioned that a lack of neuromuscular development may not only lead to higher stress during training, but may also lead higher risks of injuries (e.g. falling accidents and overuse injuries), which increases the risk of dropouts during military service.

Military BT contains a lot of endurance type activities that result in an improvement in aerobic fitness and thus cardiovascular and respiratory performance [24]. The results of the current study support this finding. VO_{2max} results increased within both groups during the first five weeks of BT, which was not observed during the rest of the period. Since the VO_{2max} test was conducted with running, which is familiar to all subjects, learning should not play a major role here. One limitation of the study may be that subjects were divided evenly into two groups according to maximal oxygen uptake, which may have caused some overlapping between the groups due to possible small measurement error in VO_{2max}. In order to keep the total number of subjects as high as possible we did not, however, dismiss possible borderline subjects but divided the group equally.

It can be concluded that insufficient development of neural and force responses is a consequence of the lack of strength training during BT. This was the case in all conscripts regardless of aerobic fitness level before training. Weaker central activity (measured as V-wave) in LF can lead to an overall decrease in performance and increased sensation of the loading and, therefore, result in interruptions from military service. According to the results of the present study, it can be suggested that at the beginning of BT the volume of explosive and/or maximal strength training should be increased. This would be recommended for all conscripts but especially those who have poor physical fitness. In addition to added strength training, the volume of endurance training should be reduced and/or appropriate periodization should be taken into account to avoid possible overreaching.

Conflict of interest: Authors state no conflict of interest.

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