Training Load and Energy Expenditure During Military Basic Training Period

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Abstract

Purpose: To compare training load and energy expenditure during an 8-week military BT period among individuals having different fitness level using objective measurements in an authentic environment.

Methods: Thirty-four voluntary male conscripts (age 19.1±0.3 years) were divided into three training groups (inactive, moderate, active) by their reported physical activity (PA) level evaluated by the International Physical Activity Questionnaire (IPAQ) prior to military service. Maximal oxygen uptake (VO_2max) and heart rate (HR) were determined by maximal treadmill test in the beginning and after 4 and 7 weeks of BT. During BT, HR monitors and accelerometers were used to measure PA and energy expenditure. HR data were used to calculate the training load (TRIMP, training impulse) for each day, week and the whole BT period.

Results: Training load of BT was comparable to training of competitive athletes at the highest level. The training groups differed ($p<0.001$-0.05) in terms of VO_2max to each other (inactive 36±6, moderate 42±6, active 48±6 ml/kg/min). The conscripts in the inactive group were the most loaded during the study period ($TRIMP_{inactive}$ 12393±2989 vs. $TRIMP_{moderate}$ 10252±1337, $p<0.05$ and $TRIMP_{active}$ 8444±2051, $p<0.01$). The PA intensity of different military tasks during the BT period were low or moderate (<6MET).

Conclusion: The remarkable training load during BT period is comparable to the training loads of professional athletes participating three weeks' cycling competition. The training load in basic training period was, however, primary due to duration of low intensity activities including only some high intensity military activities. In the future, measuring the training load during the military service is recommended in order to customize the physical training for conscripts regarding his/her fitness level as much as possible.

Key Words: Accelerometer, Heart rate monitoring, Military task, Physical activity, Training impulse

INTRODUCTION

The aerobic fitness of young men entering military service has decreased during the last decades (1,2), and this sets additional requirements for the Armed Forces for to develop the physical fitness of conscripts. Individual fitness level influences the experienced training load during the basic training (BT) period. A person with good physical fitness can work longer at the same intensity compared to the person with lower physical fitness (3). The physical fitness of the conscripts thus has an effect on the individually experienced training load during the BT period. Training load of military training can be high during the initial weeks of BT. To maintain adequate performance, the mean training load during prolonged physical activity should not exceed 50% of maximal oxygen uptake (4,5). Exceed training load increases the likelihood of becoming fatigued and or getting injured (6,7). So far, the volume and intensity of training load, and energy expenditure (EE) during the BT period in not fully understood among the conscripts of varying fitness levels (8). The goal of the BT period is to improve basic military skills of all the conscripts and the physical performance of the conscripts, especially, among least fit individuals. Especially, conscript with the lowest fitness levels are prone to getting fatigued or even injured if the training load is not tailored enough. On the other hand, in order to enhance aerobic performance, an adequate amount and intensity of physical activity is required. Thus, the physical training volume increases notably after the first weeks of BT. Therefore, there is a need to objectively define, measure and track fitness levels throughout the training in order to monitor improvements, especially in a lower fit group.

The physical performance of conscripts during the BT period is achieved by combat (34%), marching (21%), sport-related physical training (36%), and close combat (6%) training, while only 3% of BT is general military education (9). Almost half of the eight week BT period (145 hours) consists of physical training and the weekly physical training volume is approximately

25 hours (10). The risk for injury due to the training volume is at its highest at the beginning of the BT period (6,7). Thus, the intensity of the physical training during the BT period has been tailored for the conscripts in basic training period of the Finnish Defence Forces. In order to individualize the training, the conscripts are divided into training groups according to their initial physical fitness and skills in the beginning of the BT period (9,11). The physical training in the BT period is mainly endurance-based and low intensity military training, although it also includes training with higher intensities exceeding the anaerobic threshold and completed with extra load e.g. carrying personal combat gear of 25 kg (9). Environmental changes, such as temperature, relative humidity and terrain have also effects on the experienced workload (4).

Physical load during the BT period has earlier been explored using EE (8) in addition to endurance and muscular fitness measures (12,13). The physical activity (PA) dose can be explored as absolute or relative intensity of the activity or by measuring EE during days, weeks, and months (14). The absolute intensity describes the actual EE level, which can be expressed as metabolic equivalents (MET units). The MET unit is defined as the rate of EE during a specific physical activity in relation to a resting EE. The use of MET unit in defining EE enables the comparison of the different physical activities. The actual EE might remarkably differ between the physical activities and subjects since the body mass, fat percentage, age, sex, intensity, environment, and physical fitness level have been observed to have a substantial impact on EE in different modes of physical activity (15).

Maximal oxygen uptake has been observed to increase by 13.4% during the BT period (13). The improvement of maximal oxygen uptake is the greatest in conscripts with lowest preceding physical activity, approaching the aerobic fitness level of most active conscripts after the BT period (13,16). The physical load might be too low for some of the most active conscripts to achieve a positive response in maximal oxygen uptake (13). Similar results have been reported by Rosendal et al. (2003) and Dyrstad et al. (2006) during the BT period of the military services in Norway and Denmark (17,18).

Low physical fitness prior to the BT period is related to the decreased muscular strength during the last four weeks of the BT period that might be due to too strenuous or too light training (12). The mean daily EE during the BT period varies from 9 MJ (2150 kcal) to 22 MJ (5250 kcal) (4). During the most strenuous basic training weeks, the mean EE can be over 15.5 MJ (3700 kcal) (8).

Measuring individual training load and performance during the long-lasting military BT period, containing several different military activities, is challenging (8). The purpose of the present study was to investigate training load and EE during an 8-week military BT period using objective measurements in the authentic environment. The aim of the tailored physical training during the BT period is to optimize the physical load. The effective training program induces the development of fitness level over the course of the BT period. The results of this study can be utilized when investigating workload as well as physical performance, nutrition and hydration requirements during the BT period.

METHODS

Subjects

Initially 131 conscripts voluntary participated in the study. In order to minimize interindividual variation and the impact of confounding variables, only male conscripts were studied. Conscripts (N=47) with cardiovascular, respiratory or musculoskeletal diseases were excluded from the study. Thus, 84 subjects were divided into the three training groups (inactive, moderate, active) by their reported physical activity level, which was evaluated by the International Physical Activity Questionnaire (IPAQ) (19) prior to their military service.

All the subjects received heart rate monitors and accelerometers were randomly given to 34 subjects. Thirty-four voluntary male conscripts (age 19.1±0.3 years) wearing the both devices were included in the final investigation study (Table 1). The research protocol was approved by the Finnish Defence Forces and the Ethical Committees of University of Jyväskylä and the Kainuu region of Finland, in compliance with the Declaration of Helsinki and conformed to international ethical standards. Written informed consent was obtained from each subject prior to the study.

-insert table 1 here-

Experimental protocol

Physical load was studied using indirect EE measurements. During the BT period, the conscripts received the standard basic training of Finnish Defence Forces. The service day started at 5:45 a.m. and ended at 10:00 p.m. The daily activities were divided into periods of 15 min. An individualized service schedule was created for each subject according to their actualized participation in the service (team, absence, testing days, marches, shooting camps). The activities were transferred and logged as numeral codes.

Measurements

Continuous measurements of the heart rate (HR) and physical activity (PA) were used to evaluate the training load during the BT period. The relationship between the oxygen consumption and HR in the maximal aerobic performance tests were utilized to determine the volume and intensity of task related PA, the total training load of military tasks and basic training period, and to compare the training load of three training groups based on IPAQ and fitness levels.

The volunteers participated in physical performance tests at the service weeks 1, 5, 8 and 10. The performance tests were always conducted at the same time of the day. Height, body mass, resting heart rate (HR_{rest}), standing heart rate ($HR_{standing}$), maximal oxygen uptake (VO_{2max}), and maximal heart rate (HR_{max}) were measured during the performance tests (Figure 1).

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Antropometrics Body mass was measured in light clothing (t-shirt, pants) to the accuracy of 0.1kg (Model 758CSV, Detecto, USA) and height to the accuracy of 0.5cm using a stadiometer.

Resting and standing HR were recorded at the frequency of 0.2 Hz (Polar810i; Polar Electro, Kempele, Finland) during five minutes in both sitting and supine positions, before the maximal aerobic performance test.

Maximal aerobic fitness (VO_{2max}) was measured using a treadmill test. The warm-up included 3 min of walking at the speed of 4.6 km/h and 3 min jogging/walking at the speed of 6.3 km/h. The load was increased every three minutes according to the theoretical oxygen consumption (6 mL/kg/min) (ACSM 2001) until exhaustion. Breath-by-breath ventilation and respiration gases were measured continuously (Jaeger Oxygen Pro; Viasys Healthcare GmbH, Hoechberg, Saksa) and analysis was conducted in intervals of one minute. HR was recorded (Polar810i, Polar Electro, Kempele, Finland) every five seconds during the test. Blood lactate concentration (LactatePro®, Arkray, Japan) was measured one minute after the test. The criteria for maximal performance were defined as follows: stabilization of the HR despite the increase of speed or incline, respiratory quotient and blood lactate more than 1.1 and 8 mmol/L, respectively (8).

Heart rate was recorded daily between 6 a.m. and 9 p.m. at the recording rate of 0.2 Hz (Polar810i, Polar Electro, Kempele, Finland). During the night training and camps HR was recorded at one-minute intervals. The data were manually corrected by deleting the single false beats and substituting the false data lasting less than 15 min by data values from adjacent data since the activity during that time was known. The individual activity schedule was utilized in the data corrections. The false or absent data longer than 15 min was excluded from the analysis.

Physical activity was measured using accelerometers (Polar AW200, Polar Electro, Kempele, Finland). The data were collected daily around the clock using a sampling rate of one-minute.

Energy expenditure was calculated from HR and accelerometer data across the 41 days during the eight weeks' BT period. Matlab software (Mathworks, Massachusetts, USA) was used to process the data. The individualized relationship between HR and EE was defined from the maximal performance tests at the weeks 1, 5, 8 and 10. Energy expenditure (EE) was calculated using equation 1 (20).

$$EE\left(\frac{kcal}{min}\right) = 3.8455 \times \dot{V}O_2\left(\frac{l}{min}\right) + 1.2064 \times \dot{V}CO_2\left(\frac{l}{min}\right) \quad (1)$$

A third-degree polynomial function was generated to describe the relation between HR and EE values. The EE value for each HR value was calculated using the created polynomial. The individualized daily HR-EE-conversion matrix was created for each subject by interpolating the HR-EE-relations from the weeks 1, 5, 8 and 10.

Energy expenditure from the accelerometer data were calculated using curve-linear computation. The EE equation used to convert the activity pulses into the MET units was created by utilizing the double-labeled water (DLW) measurement. The details of the method have previously been described (8).

Physical Activity Energy Expenditure (PAEE). To evaluate EE of a certain physical activity, basal metabolic rate (BMR) was subtracted from the calculated HR- and activity-based EE values (Equations 2 and 3). BMR was calculated using Equation (4) (21). The daily weight and height values were interpolated using the measured values at the maximal treadmill test days.

$$PAEE_{HR}(MET) = EE_{HR}(MET) - 1 \qquad (2)$$

$$PAEE_{AC}(MET) = EE_{AC}(MET) - 1 \qquad (3)$$

$$BMR\left(\frac{kcal}{\text{min}}\right) = (15.1 \times weight(kg) + 692)/1440 \qquad (4)$$

Energy expenditure of the basic training activities. The physical activities of BT were logged into the service program, and the 15-min mean values were calculated for EE evaluated from HR and PA data. In case the 15 min epoch included data less than 8 min, EE was not calculated. The service program and EE data were synchronized to enable the determination of EE of a single PA type.

Total energy expenditure was evaluated only if at least 70% of the daily data were available. In addition, total EE data were only included from the subjects who had appropriate data from 20 measurement days or more. The training impulse (TRIMP) during the BT period was computed from the HR data using equation 5 (22).

$$TRIMP = A \times B \times C \qquad (5)$$

$$A = time(\text{min}), B = \frac{HR - HR_{rest}}{HR_{max} - HR_{rest}}, C = 0.64 \times e^{1.92B}$$

The daily HR_{max} and HR_{rest} values were interpolated from the maximal aerobic fitness test. The mean TRIMP values were calculated for each measurement day, week, and the whole BT period. The total load for each basic training task ($TRIMP_{task}$, METmin) were determined by multiplying the PA energy expenditure ($PAEE_{HR}$, $PAEE_{AC}$) with the total time spent in that activity task (Equations 6 and 7).

$$TRIMP_{task\_HR} = time(\text{min}) \times PAEE_{HR}(MET) \qquad (6)$$

$$TRIMP_{task\_AC} = time(\text{min}) \times PAEE_{AC}(MET) \qquad (7)$$

Physical Activity Level (PAL) i.e. absolute training load was evaluated from the accelerometer data throughout the BT period to compare the daily, service time, free time, and night time PA levels.

Statistical analyses

All data are presented as mean ± SD. The level of statistical significance was set at $p<0.05$. The Shapiro-Wilkinson test was used to test the normality of the data. The mean and standard deviations were calculated, and paired t-test was used to compare the activity types and TRIMP values. A one-way ANOVA was conducted to compare training and fitness groups. Post-hoc analyses were conducted using LSD pairwise comparisons. All statistical analyses were performed with SPSS (SPSS statistics 19; SPSS Inc., Chicago, USA).

RESULTS

Intensity of military tasks

The intensity of military task was determined for 72 activity types. The intensity of military tasks varied largely ranging from low to high intensity (see Appendix 1, supplemental digital content, PAEE in military tasks during the BT period). The values measured by HR (1.9 - 6.2 MET) were generally significantly higher ($p<0.001$- 0.05) compared to the accelerometer-based values (1.6 - 4.7 MET). The HR based energy expenditure value was greater than the accelerometer based values in all measured military tasks. The statistically significant difference between HR and accelerometer based EE was observed in 94% of the military tasks. However, EE measured with these two methods associated in almost half of the military tasks. The highest correlation values were observed during the more steady-state activities.

Training load

The training load of military tasks varied from 13 to 15272 METmin (see Appendix 2, supplemental digital content, The training load of military tasks during the BT period). The highest training load was accumulated during the field shooting exercise. The “top 5” tasks were field shooting training, moving to the dining hall and meal, free time, transition and boot camp.

During the eight-week BT period, the mean (±SD) total training load (TRIMP) based on HR data was 10284 (± 2609) ranging from 5576 to 17872. The weekly training load varied during the BT period remarkably (range: 991–1804) (Figure 2). The mean weekly training load was 1371 (±466). During BT weeks four and six, the training load reached its highest value and was significantly higher compared to other studied weeks. The lowest training loads were measured at the second and third training weeks. The mean daily training load was 255 (± 71) ranging from 143 to 419.

- insert Figure 2 here-

The effect of training group and fitness level on the training load

The HR data based on total training load in training groups (pre-service IPAQ: inactive, moderate, active) was significantly higher in the inactive group (12392 ± 3124) compared to moderate (10252 ± 1256, $p<0.05$) and active (8444 ± 1887, $p<0.01$) groups. There was no significant difference in training loads between the groups divided by the pre-service fitness. (Figure 3).

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The effect of the training group on weekly training impulse was observed during the first four BT weeks (Figure 4). The training load in the inactive group was greater than the moderate and active groups. The difference in the training load between the moderate and active groups was observed only at BT week 3.

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The daily absolute training load (physical activity level, PAL) calculated from accelerometer data (2.1±0.1 MET) was not observed to differ between the training groups during a total military service day (24h). However, free time PAL was significantly higher in the active group (2.6±0.2 MET) compared to inactive (2.3±0.1) or moderate (2.4±0.1 MET) groups ($p<0.01$).

DISCUSSION

To our knowledge, there are no previous studies showing detailed training load of the military BT period measured by monitoring HR and recording physical activity objectively with an accelerometer. The mean training load (TRIMP) during the BT period was 10284, which is comparable to the training loads of professional cyclists participating in the three weeks' Tour of Spain (Vuelta), since the cumulative training load for a cyclist participating the three weeks' tour is 6200-6600 (2000 per week) (24). During the BT period, the mean weekly and daily training loads were 1371 and 255, respectively. The weekly training load of professional cyclists during the rehearsal period varies from 1000 to 1500 (25), and among cross-country skiers and runners around 800 (26-28). In long-distance running, the mean daily training load ranges from 80-220 (26). Thus, the training load of conscripts in the BT period parallels with the training load of elite athletes.

Aerobic fitness has a substantial impact on physical performance and individually experienced training load that depends on the fitness level of the conscript. The present conscripts were divided into the three training groups (inactive, moderate, and active) based on their pre-service physical activity level by Finnish Defence Forces. The amount of physical activity that is required to enhance and maintain the aerobic fitness depends on an individual's fitness level at the baseline (29). The purpose of the training groups was also to compensate the training load between the conscripts.

The total training load in the inactive group was significantly higher compared to the moderate and active groups. The difference in training loads between the training groups was observed during the first four BT weeks. The attenuation of the difference in training load towards the end of the BT period might be due to improved aerobic performance and muscle strength in the inactive group. The conscripts with lower initial aerobic fitness typically improve their aerobic performance mostly during the BT period (16-18,30). The volume and intensity of the physical activity required to improve performance is known to be lesser in inactive subjects compared to the more active ones, since the dose-response relationship between the aerobic fitness and physical training load is highly progressive (31). In order to improve the performance in all of the training groups, physical training in the BT period should be customized even more regarding to conscripts' fitness level as much as possible.

Attention should be paid to the training load of the active group as well. Earlier studies have shown that the training load is too low to improve the maximal oxygen uptake in the active group (12,13,17,18).

Most of the military tasks in the present study was categorized as low or moderate intensity. Based on the HR measurement, 21% of the military tasks were conducted at low intensity (<3MET) and 78% at moderate intensity (3-6 MET). Only one military task (movement under fire) reached high intensity (>6 MET). The corresponding percentages for the accelerometer-based categorizing were 19% and 81%, respectively, and none of the military tasks reached the high intensity level. Thus, the high training load observed during the BT period was more likely caused by the long-duration than the high intensity of the activity.

The total duration of activity also has a major effect on the evaluated total training load of the military tasks ($TRIMP_{task}$, METmin). Interestingly, the general tasks such as moving from place to place (transition) and free time were observed to be among the most loading activities during the BT period. The training load of the ten most loading tasks accounted for 64% of the total training load measured during BT.

The statistically significant difference between HR and accelerometer based EE was observed in 94% of the military tasks. However, EE measured with these two methods associated in almost half of the military tasks. The highest correlation values were observed during the more steady-state activities, which is in line with earlier studies comparing these methods (23). Several factors might cause the difference between the HR- and accelerometer-based EE. An accelerometer can measure only movement-related EE. Thus, the accelerometer underestimates EE during isometric muscle contraction or when a load is carried. Military tasks during BT also include the carrying of heavy loads (9). The environmental conditions i.e. altitude, terrain, and temperature may also affect actual EE without altering EE measured by an accelerometer (32,33). These factors typically result in underestimation of EE by accelerometer. However, the double labelled water method based EE function for the accelerometer was formulated in authentic conditions during the BT period. This might improve the reliability of the accelerometer in this study. The HR measurement is also vulnerable to factors such as emotions, daily heart rate variability, hydration, nutrition status, smoking, body posture, used muscle group, and environmental factors such as temperature, humidity and altitude (34). The HR measurement commonly overestimates the actual EE. Furthermore, a linear relation between HR and EE has been observed only in moderate and high intensity activity levels (>30–100% VO_2max). At the low intensity level, HR does not increase as steeply for a given change in EE, probably due to changes in stroke between lying, sitting and standing (35). However, during the present BT period, time was also spent at a low intensity level, which might have affected the measured EE.

Despite the manually conducted data correction, we were unable to substitute or fix some parts of the lacking or false data, which is one of the limitations of this study. The amount of the signal artifact was, however, marginal and most of it was corrected during the data processing. Furthermore, the time synchronization between HR and accelerometer data was observed to be partially inaccurate in two subjects, which might slightly have affected the data. The comparable high number of the subjects, continuous measurement of data and the long duration of the study period resulted in large amount of study data, which is one of the strengths of the present study.

The results of this study can be utilized when investigating workload as well as planning physical performance, nutrition and hydration requirements during military service. In the light of this study, the conscripts with lower preservice physical activity are experiencing greater training volume during the BT period compared to others. Further studies are called for to determine if customized training based on baseline fitness levels will benefit conscripts in terms of performance, attrition, or injury. The most practical way to customize training in military settings during BT could be to share recruits in the level groups based on their initial fitness level.

Conclusions

The training load during the BT period was comparable to the daily and weekly training loads of professional athletes in pre-competition and competition periods. The high training load likely originated from long lasting military tasks instead of intensity. The results of this study can be utilized in evaluating the nutrition and hydration requirements during the BT period and planning tailored training to the conscripts.

The evaluation of physical load in authentic field condition is challenging. Both HR and PA measurement are suitable methods for the measuring of EE in field conditions, since the devices are small and do not disturb normal activity. Combining these methods may provide a more accurate estimate on the actual EE, since the accelerometer is prone to underestimate, and HR measurement typically overestimate EE.

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Conflict of Interest

Author declare no conflicts of interest. The results of the present study do not constitute endorsement by ACSM and are presented clearly, honestly, and without fabrication, falsification, or inappropriate data manipulation.

Author Contributions

Conceived and designed the experiments: MT, HKy. Performed the experiments: MT, HKy. Analyzed the data: HJ, HKi. Wrote the paper: HJ, MT, HKy, MS, HKi

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Supplemental Digital Contents

Supplemental digital content 1. PAEE in military tasks during the BT period.

Supplemental digital content 2. The training load of military tasks during the BT period.

Figure and Table captions

Table 1. Demographics.

Figure 1. Study protocol. The study measurements were conducted at weeks 1, 5, 8 and 10. Heart rate was measured during the daytime activities (6AM-9PM) and physical activity was recorded continuously around the clock by accelerometer. HR= heart rate; VO_2max= maximal oxygen uptake.

Figure 2. TRIMP weeks. The training loads (TRIMP±SD) during the 8 weeks of basic training period. As planned, the training impulse intensified during the basic training periods. The weeks 4 and 6 were the most strenuous weeks, whereas the first three weeks were the lightest weeks in the BT period. $^*p<0.05$, $^{**}p<0.01$

Figure 3. Total training load (TRIMP±SD) for the fitness (Low, Moderate, Good) and training (Inactive, Moderate, Active) groups. The training load was significantly higher in the Inactive group compared to Moderate and Active groups. $^*p<0.05$, $^{**}p<0.01$

Figure 4. Weekly training load (TRIMP±SD) in training groups (Active, Moderate, Inactive) during the 8-week basic training period. $^*p<0.05$, $^{**}p<0.01$