Aerobic fitness, energy balance, and body mass index are associated with training load assessed by activity energy expenditure

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Aerobic fitness, energy balance, and body mass index are associated with training load assessed by activity energy expenditure

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The present study examined whether activity energy expenditure related to body mass (AEE/kg) is associated with maximal aerobic fitness (VO₂max), energy balance, and body mass index (BMI) during the 2 hardest weeks of the military basic training season (BT). An additional purpose was to study the accuracy of the pre-filled food diary energy intake. Energy expenditure (EE) with doubly labeled water, energy intake (EI), energy balance, and mis-recording was measured from 24 male conscripts with varying VO₂max. AEE/kg was calculated as (EE × 0.9 − measured basal metabolic rate)/body mass. The reported EI was lower (P < 0.001) than EE (15.48 MJ/day) and mis-recording of the pre-filled diary was −20%. The negative energy balance (−6 ± 26%) was non-significant; however, the variation was high. The subjects with a low VO₂max, a high BMI, and a negative energy balance were vulnerable to low AEE/kg. However, in the multivariate regression analysis only BMI remained in the model, explaining 33% of the variation in AEE/kg. During wintertime BT, AEE/kg is affected by energy balance, VO₂max, and BMI. From these three factors, overweight limits high-level training the most. Furthermore, an optimal energy balance facilitates physical performance and enables high training loads to be sustained during the BT season.
relative to their maximum capacity at any given absolute level of aerobic work (Jones & Knapik, 1999). Thus, it could be hypothesized that the less fit conscripts will experience more physiological stress during physical activity because they have to work at higher relative intensities, and aerobic fitness is not necessarily related to AEE.

The doubly labeled water (DLW) method has been used as a gold standard for the measurement of total daily energy expenditure (EE) (Schoeller et al., 1986; Westerterp et al., 1995b). Several studies have used the DLW method in military operations, for example during rigorous field training exercise (DeLany et al., 1989; Forbes-Ewan et al., 1989; Mudambo et al., 1997; Castellani et al., 2006), in extremely cold environments (Hoyt et al., 1991; Jones et al., 1993), or in the garrison (Mudambo et al., 1997). In combination with the measurement of BMR, the DLW method allows the calculation of AEE and PAL over prolonged periods in military environments.

Energy intake (EI) has been found to influence EE and activity level (DeLany et al., 1989; Klein & Goran, 1993; Thompson et al., 1995). In addition, unfamiliar stressful situations have been found to affect EI (Popper et al., 1989). Most young men entering the military service will have their first experience of demanding physical training, eating outdoors, and performing overnight exercises in a forest. The common way to assess EI is a self-reported food diary. However, when DLW has been used to validate EI, a discrepancy between self-reported EI and measured EE has been observed, mainly due to under-reporting (Goris & Westerterp, 1999). Under-reporting can be divided into mis-recording and under-eating; mis-recording refers to a discrepancy between EI and measured EE with no change in body mass, and under-eating is a discrepancy accompanied by a decline in body mass over the food-recording interval (Goris & Westerterp, 1999), representing a negative energy balance. With a description of mis-recording, an estimate of true EI could be obtained.

No studies have examined the associations between soldiers' maximal aerobic fitness, energy balance, body size, and activity during the BT season in winter conditions. Thus, the purpose of this study was to determine the importance of VO\textsubscript{2max}, energy balance, and body size on AEE related to body mass (AEE/kg) during the 2 hardest weeks of the wintertime BT season. In the present study, the activity level (AEE/kg) equated to the training load during the entire period of BT. An additional purpose was to study the accuracy of a self-reported pre-filled food diary in the military environment without food weighing, but with known food composition.

### Methods

#### Subjects

Voluntary male conscripts (n = 24) from the Signal Battalion of Northern Finland with varying VO\textsubscript{2max} levels participated in the present 2-week study. Conscript is a definition of a person who enters compulsory military service, which is strictly performed according to the standard direction of the Defense Command. The subjects were selected from a total of 131 subjects, who volunteered for the present study. From the original subjects, 47 were discarded based on cardiopulmonary or musculo-skeletal disorders, and incomplete fulfillment or willingness to perform special duties. The remaining 84 were divided into three categories according to their level of voluntary physical activity before military service. From each category, 20 subjects were selected, yielding a total of 60 randomly ordered subjects. Finally, these 60 subjects were divided into three groups of equal numbers according to their initial VO\textsubscript{2max} (mL/kg/min) when entering military service: > 45 mL/kg/min for group 1; 40–44.9 mL/kg/min for group 2; and < 39.9 mL/kg/min for group 3. From each group, eight subjects were randomly selected, yielding a total of 24 subjects. Subject characteristics are presented in Table 1. The subjects' physical fitness characteristics were representative of young Finnish men (Santtila et al., 2006). All subjects were fully informed of the experimental protocol and gave their written consent to participate in the study. They were also advised of their right to withdraw from the investigation at any time. The study protocol was approved by the Finnish Defence Forces and the Ethics Committees of the University of Jyväskylä and the Kainuu region, respectively.

#### Study protocol

The study took place during wintertime in Finland, when daily outdoor temperatures ranged between −6°C and −19°C, with an average of −11°C (according to the local weather station). The experimental protocol is presented in Table 2. The overall physical load of the 8-week BT season was set according to the standard direction of the Defense Command. The study took place during the last 2 weeks of BT, which was the most strenuous period of the BT season. Food and water intake were ad libitum during the study. The average sleeping time at the garrison was from 10 p.m. to 5:45 a.m. Military education included physically demanding activities such as marching, combat training, and sport-related physical training. The conscripts also carried combat gear weighing 25 kg, including clothing, particularly during marching and combat training. In addition, the training included an overnight field exercise. Garrison training involved theoretical education in classroom settings, material handling, shooting, and general military education, such as close-order drills. Table 2 provides

| Table 1. Physical characteristics of the subjects (N = 24) |
|-----------------|-----------------|-----------------|
| **Age (years)** | **Height (cm)** | **Body mass (kg)** |
| 19.6 ± 0.2 | 171 ± 7.0 | 77.6 ± 14.9 |
| **Body mass index (kg/m\textsuperscript{2})** | **Fat-free mass (kg)** | **Fat mass (kg)** |
| 24.3 ± 3.8 | 59.7 ± 9.4 | 18.0 ± 9.7 |
| **Fat (%)** | **VO\textsubscript{2max} (L/min)** | **VO\textsubscript{2max} (mL/kg/min)** |
| 22.1 ± 7.9 | 3.6 ± 0.6 | 47 ± 7 |

VO\textsubscript{2max} refers to maximal oxygen uptake.
BMpost, and the change in BM (\(\text{VO}_{2\text{max}}\) demand of running (ACSM, 2001). This was achieved 3 min to induce an increase of 6 mL/kg/min in the theoretical space divided by 1.04, correcting for exchange of the \(^2\text{H}\) label with non-aqueous \(\text{H}\) of body solids (Schoeller et al., 1980).

**Anthropometry and body composition**

Body mass was measured with an accuracy of 0.01 kg (Inbody720 body composition analyzer; Biospace Co. Ltd., Seoul, Korea) at the beginning (BM\(_{\text{pre}}\)), after 1 week (BM\(_{\text{mid}}\)), and at the end of the experimental period (BM\(_{\text{post}}\)). The measurements were performed between 6:00 and 7:00 a.m. after an overnight fast and after voiding, with no exercise for 12 h before the test. The physical activities in the daily program were planned to be light on the day preceding each measurement, and fluid status was estimated to be balanced on the dietary records of the subjects. The subjects were barefoot and they wore T-shirts and trousers. The BM\(_{\text{mean}}\) was presented as an individual average of BM\(_{\text{pre}},\) BM\(_{\text{mid}},\) and BM\(_{\text{post}},\) and the change in BM (ABM) was calculated as the difference between BM\(_{\text{post}}\) and BM\(_{\text{pre}}\). Body height was measured to the nearest 0.5 cm using a wall-mounted stadiometer. Body mass index (BMI) was calculated as BM\(_{\text{pre}}\) divided by the body height squared. Fat-free mass (FFM) was calculated from total body water (TBW) as follows: FFM = TBW/0.732 (Pace & Rathburn, 1945). Fat mass (FM) was calculated as BM\(_{\text{pre}}\) – FFM, and percentage of body fat as FM/BM\(_{\text{pre}}\) × 100. TBW was measured with deuterium dilution according to the Maastricht protocol (Westerterp et al., 1995b). TBW was calculated as the \(^2\text{H}\) dilution space divided by 1.04, correcting for exchange of the \(^2\text{H}\) label with non-aqueous \(\text{H}\) of body solids (Schoeller et al., 1980).

**BMR**

The BMR was measured once, for practical reasons, \(\sim\) 19 days before the DLW period. After an 11-h fast, the subject woke up at 5:30 a.m. for BMR measurements performed in a semi-recumbent position, lying for 30 min in a quiet room. Oxygen consumption and carbon dioxide measurements were made with the same gas analyzer (Jaeger Oxygen Pro) as that used in the VO\(_{2\text{max}}\) test. BMR was automatically calculated from the oxygen and carbon dioxide values as follows: EE = 1.59 × V\(\text{CO}_2\) + 5.68 × V\(\text{O}_2\) – 2.17 × urinary nitrogen (Weir, 1949), where urinary nitrogen was assumed to be 15 g/day. In the analysis, BMR was determined during the last 15 min of the 30-min measurement period.

**EE, AEE, AEE/kg, and PAL**

EE was measured with DLW according to the Maastricht Protocol (Westerterp et al., 1995b). Briefly, at 10:00 p.m., before the measurements and after collecting a baseline urine sample, the subjects drank a weighed mixture of \(^2\text{H}_2\text{O}\) (99.9 at%) and \(^1\text{H}_2\text{O}\) (10 at%), resulting in an initial excess TBW enrichment of 150 p.p.m. for deuterium and 300 p.p.m. for oxygen-18. TBW was estimated from calculated body composition, based on height, weight, age, and gender, using the equation of Deurenberg et al. (1991), assuming a 73% hydration of FFM. Subjects consumed no foods or fluids for 10 h after dose administration, during the overnight equilibration of the isotopes with the body water. Subsequent urine samples were collected from the second and the third voiding on the morning of day 1, and from the first and the second voiding on the morning of days 8 and 15. Isotope quantities
(deuterium and oxygen-18) in the urine were measured using an isotope ratio mass spectrometer (Optima, VG Isogas, Middlewich, UK), and CO₂ production was calculated from isotope ratios at the baseline, and days 1, 8, and 15, using the equations of Schoeller et al. (1986). CO₂ production was converted to daily metabolic rate using an energy equivalent based on the individual macronutrient composition of the diet (Black et al., 1986). AEE was calculated as EE × 0.9 – BMR, assuming diet-induced thermogenesis of 10% (Poehlman, 1989). To remove the confounding effect of body size (Ekelund et al., 2004), AEE was adjusted for BMmean (AEE/kg). PAL was calculated as EE/BMR.

EI
For studying EI, the subjects kept a pre-filled food diary for 3-4 days in two phases. Altogether, habitual food intake was obtained from 7 days during the study. The pre-filled food diary included information about the food served in the military. Details of the food and fluids that were served, including their composition, were known beforehand, and this information was written in the pre-filled diary. Thus, the subjects were only required to record the amount of food and fluid that they consumed. The subjects had completed these diaries twice before the study to ensure that they were familiar with reporting food intake. The subjects received detailed verbal and written instructions about common household measures, such as cups and tablespoons, and specific information about the quantity of the measurements. They were asked to record brand names of every non-military food that they consumed, as well as their cooking methods. In addition, they were advised to be as accurate as possible in recording the amount and type of food and fluid consumed. Any questions, ambiguities, or omissions were resolved individually and controlled via personal interviews, which included questions about whether they ate less during the recording period (under-eating) or wrote down everything they consumed (mis-recording). Daily nutritional consumption was quantified by the computer program Nutrica® software (version 3.11, Finland). The recipes of the food that was consumed in military conditions were added to the database.

Accuracy of the food diary and estimated true EI
Estimated true EI (TrueEI) was calculated using EI and changes in body energy stores (ΔES), which was calculated from changes in body mass, assuming that a body mass of 1 kg is equivalent to 30 MJ (75%FM, 25% FFM, with 73% water; Westerterp et al., 1995a). Under-reporting, mis-recording, under-eating (energy balance), and TrueEI were calculated as follows:

\[
\text{Under-reporting (\%)} = \left(\frac{\text{EI} - \text{EE}}{\text{EE}}\right) \times 100
\]
\[
\text{Mis-recording (\%)} = \left(\frac{\text{EI} - \text{ΔES} - \text{EE}}{\text{ΔES}}\right) \times 100
\]
\[
\text{Under-eating (\%)} = \frac{\text{ES}}{\text{study days}} \times 100
\]
\[
\text{TrueEI} = \text{EI} - \text{mis-recording} = \text{EI} - \left(\frac{\text{EI} - \text{ΔES} - \text{EE}}{\text{ΔES}}\right)
\]
\[
= \text{ΔES} + \text{EE}
\]

Statistical analysis
Changes in BM were tested by a paired samples t-test. FM was transformed to reduce skewness. To remove the potential effect of body size on VO₂max, FFM-adjusted values for VO₂max (VO₂maxFFM) were calculated according to the method described by Toth et al. (1993). Pearson correlation coefficients were computed to determine the linear relationship between EE, AEE, AEE/kg, PAL, BMR, and VO₂maxFFM (L/min), energy balance, and body composition (BMpre, FM, FFM, and BMI). To examine the effects of BMI, fitness, and under-eating on AEE/kg, the subjects were divided into tertiles with equal numbers of subjects according to their BMI (<22.5 kg/m² for LowBMI; 22.6-24.8 kg/m² for ModerateBMI; and >24.9 kg/m² for HighBMI), VO₂maxFFM (<3.44 L/min² for LowFIT; 3.45-3.68 L/min² for ModerateFIT; and >3.69 L/min² for FIT), and energy balance (>0.76 MJ/day for Low; <2.16-0.75 MJ/day for Moderate; and < <2.17 MJ/day for High under-eating). One-way ANOVA with the LSD post hoc test was used to compare the differences in AEE/kg, energy balance, and fitness or BMI between the category groups. For further evaluation of the interaction and to identify the predictors of AEE/kg from the independent variables, multivariable linear regression analysis was used. The independent variables were VO₂maxFFM (L/min), body composition, and energy balance. The final model was computed after the multicollinearity diagnostic and the assumptions for regression analysis were fulfilled. All statistical analyses were performed using SPSS (14.0.1. 2005; SPSS Inc., Chicago, Illinois, USA). The level of statistical significance was set at P<0.05.

Results
BMR (7.66 ± 0.92 MJ/day) represented 50 ± 5% and AEE (6.26 ± 1.21 MJ/day) 40 ± 5% of the total EE (Table 3). The reported EI of 11.5 ± 3.2 MJ/day was significantly lower than the measured EE (15.5 ± 1.6 MJ/day), and thus the results revealed significant under-reporting (−26.0 ± 17.5%, P<0.001). The data of reported intake indicated that daily carbohydrate consumption in relation to the total reported EI was 58 ± 4% (5.2 ± 1.6 g/kg), fat 27 ± 4% (1.1 ± 0.4 g/kg), protein 14 ± 2% (1.3 ± 0.4 g/kg), and alcohol 0.3 ± 0.9% (0.01 ± 0.04 g/kg). When the reported EI was corrected for the mis-recording

Table 3. Energy expenditure (EE), its components, and energy intake (EI) variables in 24 conscripts

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean ± SD</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE (MJ/day)</td>
<td>15.48 ± 1.65</td>
<td>12.75–18.51</td>
</tr>
<tr>
<td>AEE (MJ/day)</td>
<td>6.26 ± 1.21</td>
<td>4.18–8.94</td>
</tr>
<tr>
<td>AEE/kg (MJ/day/kg)</td>
<td>0.05 ± 0.02</td>
<td>0.04–0.13</td>
</tr>
<tr>
<td>PAL</td>
<td>2.03 ± 0.21</td>
<td>1.68–2.47</td>
</tr>
<tr>
<td>BMR (MJ/day)</td>
<td>7.66 ± 0.92</td>
<td>5.50–9.44</td>
</tr>
<tr>
<td>EI (MJ/day)***</td>
<td>11.52 ± 3.32</td>
<td>6.73–17.77</td>
</tr>
<tr>
<td>Estimated true EI (MJ/day)</td>
<td>14.62 ± 4.17</td>
<td>4.90–22.35</td>
</tr>
<tr>
<td>Under-reporting (%)</td>
<td>−26.0 ± 17.5</td>
<td>−52.4–5.6</td>
</tr>
<tr>
<td>Under-eating = energy balance (%)</td>
<td>−5.6 ± 25.5</td>
<td>−66.3–41.7</td>
</tr>
<tr>
<td>Mis-recording (%)</td>
<td>−20.4 ± 26.3</td>
<td>−82.9–29.5</td>
</tr>
</tbody>
</table>

*Calculated as EE/BMR.
** Difference with EE (P<0.001).
***AEE, activity energy expenditure; AEE/kg, activity energy expenditure related to body mass; PAL, physical activity level; BMR, basal metabolic rate.
AEE, VO<sub>2max</sub>, energy balance, and BMI

AEE/kg was also lower in LowFIT compared with ModerateFIT and FIT (P<0.05) (Fig. 2b), but BMI and energy balance did not differ between these three fitness groups. Furthermore, AEE/kg was lower among subjects in the High under-eating group compared with the Low and Moderate under-eating groups (P<0.01) (Fig. 2c). These subjects also had higher BMI (27.8 ± 3.6 kg/m²) compared with subjects in the Low (21.4 ± 2.4 kg/m², P<0.001) and Moderate (23.6 ± 1.9 kg/m², P<0.01) under-eating groups and lower VO<sub>2maxFFM</sub> (3.43 ± 0.27 L/min²) compared with the Moderate under-eating group (3.75 ± 0.28 L/min², P<0.05). The Moderate and Low under-eating groups did not differ in AEE/kg, BMI, or VO<sub>2maxFFM</sub>.

VO<sub>2maxFFM</sub> was positively related to AEE and AEE/kg (r = 0.44, P<0.05 and r = 0.41, P<0.05, respectively), but it had no relationship with EE (Table 4). BMI was negatively related to AEE/kg (r = −0.60, P<0.01) but it also had no relationship with EE or AEE (Table 4). In addition, in spite of the fact that BMI did not change (−0.4 ± 1.8 kg, NS) during the 2-week training period, energy balance was related to AEE/kg (r = 0.58, P<0.01) (Table 4).

Table 5 shows the multivariate regression equations for explaining variation in AEE/kg. The model included energy balance, VO<sub>2maxFFM</sub>, and BMI. Only BMI remained in the model by explaining 33% of the variation in AEE/kg, with a standard error of estimate (SEE) of 0.02 MJ/day/kg or 25% of the mean AEE/kg.

Table 4. Pearson correlation coefficients between BMI, VO<sub>2max</sub>, and energy balance and EE, AEE, AEE/kg, and BMR

<table>
<thead>
<tr>
<th>BMI (kg/m²)</th>
<th>VO&lt;sub&gt;2max&lt;/sub&gt; (L/min)</th>
<th>VO&lt;sub&gt;2maxFFM&lt;/sub&gt; (L/min)*</th>
<th>Energy balance (MJ/day)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EE (MJ/day)</td>
<td>0.30</td>
<td>0.77***</td>
<td>0.29</td>
</tr>
<tr>
<td>AEE (MJ/day)</td>
<td>−0.70</td>
<td>0.44*</td>
<td>0.44*</td>
</tr>
<tr>
<td>AEE/kg (MJ/day/kg)</td>
<td>−0.60**</td>
<td>−0.16</td>
<td>0.41*</td>
</tr>
<tr>
<td>BMR</td>
<td>0.58**</td>
<td>0.66**</td>
<td>−0.10</td>
</tr>
</tbody>
</table>

P<0.05. **P<0.01. ***P<0.001.
*VO<sub>2max</sub> adjusted by FFM using a regression-based approach (Toth et al., 1993).

EE, energy expenditure, AEE, activity energy expenditure; AEE/kg, activity energy expenditure related to body mass; BMR, basal metabolic rate; FFM, fat-free mass.

Table 5. Multivariate regression model for explaining the variation in AEE/kg (MJ/day/kg)

<table>
<thead>
<tr>
<th>Prediction equation</th>
<th>Adjusted-&lt;i&gt;R&lt;/i&gt;&lt;sup&gt;2&lt;/sup&gt;</th>
<th>SEE</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEE/kg = 0.165 − (BMI × 0.003)</td>
<td>0.33</td>
<td>0.02</td>
<td>0.002</td>
</tr>
</tbody>
</table>

AEE/kg, activity energy expenditure related to body mass.
Discussion

To our knowledge, there are no previous reports showing a relationship between VO2max and activity (AEE/kg) during the BT season. The hypothesis was that the less fit conscripts would experience more physiological stress during physical activity, and that aerobic fitness would not be related to AEE/kg. Our contrary findings might partly be explained by the more intense participation and engagement of fit conscripts in military training. Moreover, in field situations the fit soldiers were often called upon to perform more military tasks. In support of this theory, endurance-trained cyclists have been found to have a significantly greater energy cost of cycling at the same relative intensity than untrained, less fit controls. This was due to the lower required workload of the less fit subjects to increase their heart rate to 75% of maximum, and thus their EE was also low (Horton et al., 1994). In contrast, during high-intensity activities, the low absolute work capacity of the least-fit subjects might limit their work ability.

The strength of the present study was the use of a regression-based approach to remove the confounding influences of BM or FFM, rather than a standard ratio approach to express VO2max values relative to BM (mL/kg/min). The ratio method could lead to a significant and positive intercept, resulting automatically in higher values for lighter subjects (Toth et al., 1993). In the present study, the intercept for the regression of VO2max with BM was significantly different from 0 ($P<0.01$), but with FFM it was not. The best predictor of VO2max (L/min) was FFM, with a variation of 75% ($r = 0.87$, $P<0.001$) compared with BM with the respective variation of 35% ($r = 0.60$, $P<0.01$). We therefore adjusted VO2max for FFM. Very few studies have used DLW to estimate the relationship between AEE or EE and VO2max (Ambler et al., 1998; Brochu et al., 1999).

Our results are well in line with the study of Brochu et al. (1999), where they found a significant relationship between VO2max and AEE in older individuals. The total EE in this study was similar (15.5 MJ/day) to that measured on a hilly terrain with temperatures ranging from $-1.1$ $^\circ$C to $16.1$ $^\circ$C (14.24 MJ/day) (DeLany et al., 1989) and to a group of soldiers working in the garrison (Mudambo et al., 1997). However, the present EE was lower than that measured in jungle warfare (Forbes-Ewan et al., 1989), in a winter military training course (Hoyt et al., 1991; Jones et al., 1993), and in a commando field exercise in a hot and dry climate (Mudambo et al., 1997). The mean ($\pm$ SD) total EE of all male military personnel ($N = 424$) is reportedly 19.3 ± 2.7 MJ/day across all activities, military occupational specialties, and environments (Tharion et al., 2005). Comparisons in EE between the present study and other studies should be made with caution. For example, there are possible differences in the body mass of the subjects and in the combat gear that was carried, both of which affect the total EE.

In the multivariate regression analysis, only BMI remained in the model, although the correlation and one-way analysis revealed that positive energy balance and good fitness level were also related to higher activity (AEE/kg). In other words, the slimmer the subject, the smaller the loss of BM. This also suggests that more active subjects exhibit greater levels of aerobic fitness. This was partly explained by the fact that under-eating (negative energy balance) was negatively related to BMI. Thus, especially the subjects with a higher BMI were more prone to lose body mass than their slimmer counterparts. Even though negative energy balance was not significant ($-5.6\%$) at the group level, the individual variation in energy balance ranged from $-66.3\%$ to $41.7\%$. Based on Fig. 1, one-third of the subjects had a negative energy balance. However, in the present subjects, of whom one-third ($n = 8$) had a BMI over 25, the acceptable tolerance limit for serious under-eating classification is critical. The positive relationships observed between TrueEI and EE (Fig. 1), and between energy balance and AEE/kg are well in line with other studies, where a low EI in males was found to be related to low EE (DeLany et al., 1989; Thompson et al., 1995), as well as to spontaneous physical activity (Thompson et al., 1995) when compared with an adequate EI group. Moreover, it has been shown that EE and AEE increase simultaneously with an increase in EI, which might be partly a reflection of EI to BMR (Klein & Goran, 1993). However, Castellani et al. (2006) presented a contrary conclusion. They found that during a short period ($54$ h) of physical loading, recruits were able to maintain high EE and PAL despite sustaining substantial energy deficits.

The PAL value of 2.0 obtained during the present wintertime BT is comparable with values from people performing very strenuous work or daily competitive athletic training (Nordic Nutrition Recommendations, 2004). In addition, some subjects also ate less than required. If these stressors, together with other stressors, affect soldiers for a longer period, overtraining symptoms may occur (Meeusen et al., 2006). If the BMI is used as an index of body size, it was not associated with AEE, but was negatively related to AEE/kg and positively to BMR (Table 4). Our findings further showed that BMR did not have any relationship with VO2max, but it was negatively related to AEE/kg. Among children it has been observed that AEE and EE tend to increase more with increasing body size than BMR (Ekelund et al., 2002). However, this was not seen in the present study, in which most military tasks were performed
at low-to-moderate intensity levels. This meant that the least-fit subjects were able to perform those tasks well.

An additional purpose of the present study was to investigate the accuracy of a pre-filled food diary. Great care was taken to evaluate EI as correctly as possible without food weighing. In spite of the careful guidance and control, mis-recording was as high as –20% and EI was only 74% of EE. It has been found that subjects who accurately reported their food intake at the first attempt were also able to do so at the second attempt (Goris et al., 2001). On the other hand, it is known that accuracy will decrease if the minimum recording time of 7 days is extended. This happens due to a decline in motivation in keeping the food diary (Goris et al., 2001). The calculation of under-eating, mis-recording, and an estimate of true EI were all based on changes in body ES, in which the energy content of 30 MJ corresponds to 1 kg of body mass. However, the mass ratio of 30 MJ/1 kg for storage or mobilization of energy between FM and FFM might differ individually, affecting the present results. We could have measured changes in body ES based on changes in FM and FFM, but 2 weeks may be too short a period to measure these parameters with sufficient accuracy. A more accurate method to estimate mis-recording and to calculate true EI involves a measure of water balance (Goris & Westerterp, 1999), but this method still requires the recoding of food and fluid intake, which are both prone to mis-recording (Goris & Westerterp, 1999; Goris et al., 2001; Westerterp & Goris, 2002; Tharion et al., 2005).

Perspectives

The fitness level of Finnish young men has decreased with a concurrent increase in body mass (Santtila et al., 2006). Consequently, some conscripts entering compulsory military service have a low fitness level. However, the same program has to be performed by all conscripts in the military environment. The goal of physical training during the basic training season (BT) is to increase soldiers’ aerobic fitness and muscle strength to prepare them for demanding military tasks. This leads to the question of whether fitness or body size affects the ability to train. In this study, the training load was assessed by relating activity EE to body mass (AEE/kg). The subjects with a low VO_2max, a high BMI, and a negative energy balance were vulnerable to low AEE/kg, but out of these three factors only BMI remained in the multivariate regression model. This indicates that overweight may limit the most the high-intensity physical training. In order to enhance physical fitness in a group of conscripts who exhibit variable fitness levels, these results suggest that conscripts could be divided into training groups simply based on BMI, rather than aerobic fitness level or a combination of these parameters.

Another issue is the importance of energy balance in sustaining a high training load. The results confirm that during BT, physical performance is affected by aerobic fitness and BMI as well as by energy balance. Initially, BMI has to be taken into consideration. Thereafter, energy balance should be optimized to facilitate physical performance, and to allow a high training load to be sustained during the BT season. This situation is comparable with that of athletes: without adequate EI, high-level training is not possible. Thus, because energy balance influenced AEE/kg, conscripts should be advised about adequate EI, especially during the most strenuous training period.

Key words: AEE, PAL, energy intake, under-reporting, under-eating, military training.

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