Physical Activity Levels to Estimate the Energy Requirement of Adolescent Athletes

Anja Carlsohn, Friederike Scharhag-Rosenberger, Michael Cassel, Josefine Weber, Annette de Guzman Guzman, Frank Mayer
University of Potsdam

Adequate energy intake in adolescent athletes is considered important. Total energy expenditure (TEE) can be calculated from resting energy expenditure (REE) and physical activity level (PAL). However, validated PAL recommendations are available for adult athletes only. Purpose was to comprize physical activity data in adolescent athletes and to establish PAL recommendations for this population. In 64 competitive athletes (15.3 ± 1.5yr, 20.5 ± 2.0kg/m²) and 14 controls (15.1 ± 1.1yr, 21 ± 2.1kg/m²) TEE was calculated using 7-day activity protocols validated against doubly-labeled water. REE was estimated by Schofield-HW equation, and PAL was calculated as TEE:REE. Observed PAL in adolescent athletes (1.90 ± 0.35) did not differ compared with controls (1.84 ± 0.32, p = .582) and was lower than recommended for adult athletes by the WHO. In conclusion, applicability of PAL values recommended for adult athletes to estimate energy requirements in adolescent athletes must be questioned. Instead, a PAL range of 1.75–2.05 is suggested.

A well-balanced, adequate dietary intake is essential for health and athletic performance (14,22). Intensive or prolonged exercise results in higher energy and nutrient requirements, and nutritional demands of competitive athletes may differ from those of the general population (15). However, appetite and hunger are no reliable marker of nutrient and energy requirement of an athlete (14). Thus, counseling athletes to consume a well-balanced diet with adequate energy intake might be the primary goal of dieticians and is considered the most important factor in the field of sports nutrition (3,4,10).

For this purpose a valid estimation of the subject’s current energy requirement is needed. Dieticians rely on feasible, yet reliable methods to estimate the energy requirement in athletes. Algorithms that calculate total energy expenditure (TEE) based on resting energy expenditure (REE) and physical activity level (PAL) are advantageous and often used in the daily routine, as the estimated energy demand
is immediately available without any elaborate examination. However, when estimating an athlete’s energy requirement, determination of the PAL factor is most crucial. WHO suggests a range of PAL values between 2.0 and 2.4 for adults with vigorously active lifestyles (7). This range is given based on the mean PAL ± 8% considering the variation around the mean observed in vigorously active adults. The same activity factors are recommended by the German Nutrition Society for heavy occupational work as observed in high-performance athletes (8). For lightly to moderately active adolescents aged 12–18 years WHO suggest PAL values ranging from 1.50 to 1.85 in males and from 1.50 to 1.75 in females based on data published by Torun (7,25). Few studies aimed to analyze activity levels in adolescents with heavy physical activity or with a scheduled training program (5,13,25). Here, PAL values ranging from 2.00 to 2.15 have been observed (7,25).

However, studies analyzing energy expenditure and/or physical activity level in adolescent competitive athletes are lacking, and no recommendations of PAL factors are available for this population. Intensity and duration of exercise sessions as well as periods of rest and recovering thereafter might differ in adolescents compared with adults. Therefore, a systematic bias may occur if PAL factors that have either been validated in adults or in nonathletic adolescents are used to estimate energy expenditure in adolescent athletes. The purpose of the study was therefore to analyze PAL factors in adolescent competitive athletes, and to derive recommendations for PAL factors in this population.

**Methods**

**Subjects and Study Design**

The study was conducted in a cross-sectional design with a total of 64 competitive athletes who were recruited from a school with emphasis on competitive physical education located at one of the German Olympic Sports Centres. The study included 42 female athletes (15.6 ± 1.4 yr, 20.7 ± 1.9 kg/m²) and 22 male athletes (14.8 ± 1.6 yr, 20.2 ± 2.2 kg/m²) who were engaged in track and fields (N = 32), soccer and handball (N = 14), rowing and canoeing (N = 10) or swimming and triathlon (N = 8). The control group consisted of 14 moderately active adolescents who did not participate in competitions and who were matched for age and body mass index (8 females: 15.0 ± 1.1 yr, 21.0 ± 2.3 kg/m², 6 males: 15.2 ± 1.2 yr, 21.0 ± 2.0 kg/m²).

Before participation in the research project, all candidates completed a short questionnaire to determine eligibility. Inclusion criteria comprised a habitual training frequency of ≤ 5 times per week and participation in competitions for athletes and ≥ 3 times recreational physical activity per week for controls. Recent injuries or diseases that might affect habitual physical activity or training during the 7-day measurement period were reasons for exclusion from the study. Data were obtained within six weeks to avoid changes in physical activity due to seasonal variations (17,18). All subjects and their parents gave written informed consent after the study was approved by the local ethics committee.

**Anthropometric Measurements**

Anthropometric measurements (height, weight, percentage body fat) were conducted in a fasting state, using bioelectrical impedance analysis for the estimation
of percentage body fat (Multifrequency Body-Composition Analyzer 2000-M, Data-Input, Frankfurt/Main, Germany). Fat-free mass (FFM) as the major component of REE was calculated from body weight and body fat (24).

**Resting Energy Requirement**

Resting metabolic rate (REE) was estimated using the Schofield-HW equation which was shown to be valid in children and adolescents and considers both age and gender (21,23):

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\text{REE in females (10-18 yr of age) [kcal/24 hr]} = 8.365 \times \text{BW [kg]} + 4.65 \times \text{Height (cm)} + 200
\]

\[
\text{REE in males (10-18 yr of age) [kcal/24 hr]} = 16.25 \times \text{BW [kg]} + 1.372 \times \text{Height (cm)} + 515.5
\]

**Total Energy Expenditure**

Total energy expenditure (TEE) was analyzed during a habitual training period using an activity protocol validated by doubly-labeled water technique (12). Here, subjects were requested to record their physical activity in 15 min intervals on seven consecutive days by marking the respective activity item. To reduce the number of activity items in the protocol activities with similar metabolic equivalent (MET) intensities are presented in the same line (2). Validation of this protocol in nonobese female and male subjects aged 19–64 years showed a good agreement between estimated TEE based on the protocol and TEE measured with doubly-labeled water (\(r = .88\)). The difference between PAL calculated based on activity records and PAL calculated based on doubly-labeled water technique was not statistically different from zero in the validation study (12). To account for higher energy costs in adolescents compared with adults for a given task or physical activity (19,20), adult MET values (1) were combined with age-specific REE as recommended by Ridley et al. (19).

Briefly, adult MET values were multiplied by age-specific REE as presented by Harrell et al. (9). In the recent study, adult MET values were age-adjusted using resting energy expenditure of 1.34 kcal/kg/h for females aged 12–14 years and males aged 13–15 years. For older participants, an EE of 1.16 kcal/kg/h was used to multiply with adult MET values (9).

**Physical Activity Level**

As TEE is a multiple of REE depending on physical activity, physical activity level (PAL) was calculated as TEE [kcal/24 hr]: REE [kcal/24 hr].

**Data Analysis**

Resting and total energy expenditure, energy expenditure during exercise training and PAL factors were calculated for each individual. Data are presented as means ± SD, and 95% confidence intervals (95% CI) are additionally given. To test for normal distribution of PAL factors in the entire group, Shapiro-Wilk test was used. One-way ANOVA was calculated to test for differences between female and male
athletes and female and male controls (α = .05). Post hoc Tukey-Kramer test was used to identify differences between female and male athletes and female and male controls. In addition, percentage of athletes and controls with PAL factors below or above WHO recommendations were calculated. As suggested by others (7), PAL recommendations for adolescent athletes are presented as a range, and were calculated as mean ± 8%. All statistical calculations were conducted using JMP statistical software version 5.0.1.

Results

Subjects’ Characteristics

Mean age of participants was 15.3 ± 1.4 years (95% CI: 14.9–15.6 years). Body mass index and percentage body fat did not differ between athletes (20.5 ± 2.0 kg/m²; 17.7 ± 7% body fat) and controls (20.9 ± 2.0 kg/m²; 18.6 ± 8% body fat; p = .461). Detailed subjects’ characteristics are shown in Table 1.

Resting Metabolic Rate and Total Energy Expenditure

REE was calculated 1714 ± 168 kcal/24 hr (95% CI 1671 kcal/24 hr to 1756 kcal/24 hr) in athletes and 1708 ± 151 kcal/24 hr (95% CI 1622 kcal/24 hr to 1796 kcal/24 hr) in controls (p = .921).

Estimated energy expenditure for sports activities was higher in athletes (1198 ± 650 kcal/24 hr; 95% CI: 1035–1360 kcal/24 hr) compared with controls (794 ± 593 kcal/24 hr; 95% CI: 451–1136 kcal/24 hr; p = .036). However, calculated

| Table 1 | Subjects’ Characteristics for Athletes and Controls |
|---|---|---|---|---|---|
| | Males | | Females | | |
| | Athletes | Controls | Athletes | Controls | p<sup>1</sup> |
| Age [years] | 14.8 ± 2 | 15.2 ± 1 | 15.7 ± 1 | 15.0 ± 1 | 0.123 |
| Height [cm] | 175 ± 11<sup>a,b</sup> | 171 ± 10 | 167 ± 7<sup>a</sup> | 165 ± 4<sup>b</sup> | 0.003 |
| Weight [kg] | 62.2 ± 12 | 61.7 ± 0 | 57.9 ± 8 | 57.5 ± 8 | 0.325 |
| BMI [kg/m²] | 20.2 ± 2 | 21.0 ± 2 | 20.7 ± 2 | 21.0 ± 2 | 0.669 |
| Body fat [%] | 9.6 ± 6 | 12.2 ± 7 | 21.9 ± 5 | 23.4 ± 5 | <0.001<sup>*</sup> |
| FFM [kg] | 56.2 ± 8 | 54.7 ± 8 | 46.5 ± 5 | 45.2 ± 3 | <0.001<sup>*</sup> |
| REE [kcal/24 hr] | 1765 ± 205 | 1752 ± 178 | 1686 ± 139 | 1676 ± 130 | 0.256 |
| TEE [kcal/24 hr] | 3635 ± 828<sup>a,b</sup> | 3718 ± 524 | 3100 ± 715<sup>b</sup> | 2733 ± 348<sup>a</sup> | 0.030 |
| PAL [a.U.] | 2.03 ± 0.04<sup>a</sup> | 2.12 ± 0.26<sup>b</sup> | 1.83 ± 0.34 | 1.63 ± 0.13<sup>a,b</sup> | 0.004 |

Data are presented as means ± SD.<sup>1</sup> One-way ANOVA (α = .05)

<sup>a,b</sup> Same letters in one row demonstrate significant post hoc differences (Tukey-Kramer test, p < 0.05)

<sup>*</sup> Significant differences between genders only.
total energy expenditure did not differ between athletes and controls (3292 ± 794 kcal/24 hr; 95% CI: 3094 kcal/24 hr to 3491 kcal/24 hr for athletes and 3155 ± 653 kcal/24 hr; 95% CI: 2778 kcal/24 hr to 3533 kcal/24 hr for controls; \( p = .550 \)).

**Physical Activity Level (PAL)**

Mean PAL observed in athletes was 1.90 ± 0.35 (95% CI: 1.80–1.99) and did not differ compared with moderately active controls (1.84 ± 0.32; 95% CI: 1.65–2.02; \( p = .582 \)). In 40 athletes (63% of the participants) a PAL factor below WHO recommendations of 2.0–2.4 for adult athletes was observed (Figure 1). Nine athletes (14%) documented physical activity exceeding the PAL factor recommended by WHO for adult athletes. In controls, 9 individuals (64%) showed a PAL above recommendations for lightly to moderately active adolescents (Figure 2).

In male controls documented PAL appeared to be significantly higher compared with females (2.13 ± 0.26 versus 1.63 ± 0.13; \( p < .01 \)) whereas nor difference in PAL value was observed between male and female athletes (2.03 ± 0.34 versus 1.83 ± 0.34; \( p > .05 \)). Recommendations which consider 8% variation around the mean were calculated 1.75–2.05 for adolescent athletes and 1.69–1.98 for moderately controls.

*Figure 1* — PAL values for male and female adolescent athletes. Figure legend: Box plots represent median, upper and lower quartile of PAL values in adolescent athletes. PAL range suggested by WHO and German Nutrition Society for adult athletes is shown as a shaded bar.
An increasing number of adolescents participate in high-performance training and competitions, however, no validated PAL factor recommendations are available to feasibly estimate energy requirements of adolescent competitive athletes. The purpose of the study was to analyze physical activity levels of adolescent competitive athletes aged 12–18 years. It was assumed that PAL of adolescent athletes differs from nonathletic adolescents and might be relevantly lower than recommended for adult athletes by WHO and German Nutrition Society (7,8).

Indeed, mean PAL of adolescent athletes in the current study indicates that PAL in the majority of this special population is lower than suggested for adult athletes by WHO and German Nutrition Society. This observation is even more pronounced in female adolescent athletes compared with males. In both adolescent athletes and controls males exhibited significantly higher activity levels compared with the females. In addition, PAL observed in adolescent athletes is lower than reported by others for vigorously active adolescents (25). More than 60% of adolescent athletes exhibited a PAL factor below the lower limit of PAL recommendations by WHO for adults. Training frequency of adolescent athletes might be similar compared with adult athletes. However, duration of exercise sessions as well as exercise intensities may be lower, resulting in a reduced total physical activity compared with adult athletes.

**Figure 2** — PAL values for male and female moderately active adolescents

Figure legend: Box plots represent median, upper and lower quartile of PAL values in moderately active adolescent. PAL range suggested by WHO for lightly to moderately active adolescents is shown as a shaded bar.
Surprisingly, neither total energy expenditure nor PAL factor was elevated in adolescent competitive athletes compared with controls, though energy costs for exercise training was significantly higher in athletes. It might be assumed that the athletes’ need to rest and recover following training sessions may affect leisure time physical activity, while nonathletic adolescents might show a more physically active behavior in their leisure time. Subsequently, reduced leisure time physical activity may compensate for higher energy expenditure during training in adolescent athletes. A similar impact of exercise on leisure time activity was reported by Kriemler et al. in obese boys (13). A high-intensity training program induced a decrease of spontaneous physical activity, resulting in a failure to elevate TEE in obese boys by exercise training. Westerterp et al. studied physical activity in adult novice runners starting an exercise program to complete a half-marathon. Following an initial increase, PAL remained constant although training effort was doubled by the runners (27). In contrast, McLaughlin et al. did not observe an effect of scheduled exercise on spontaneous physical activity in lean males and females aged 20–25 years (16). Eiholzer et al. even reported an increase of spontaneous physical activity energy expenditure in adolescent boys playing ice hockey, when high-intensity resistance training was added to the routinely training schedule over 12 month (5). Therefore, alterations in leisure time activity due to scheduled exercise programs may occur in both adults and adolescents and should be considered when defining a PAL factor for athletes to estimate energy demands.

In contrast to adolescent athletes, PAL values observed in controls were consistent with literature. Physical activity analysis in lightly to moderately active 10–13-year old children by activity diaries resulted in PAL factors ranging from 1.20 to 1.87 (11). Ekelund et al. analyzed TEE by heart rate monitoring in randomly selected 14–15 year old adolescents and calculated a mean PAL of 1.67 and 1.74 in girls and boys, respectively (6). Using the same technique, Vermorel and colleagues observed a physical activity level of 1.76 in 14–16 year old boys (26). Based on data published by Torun, WHO suggests PAL ranging from 1.50 to 1.85 for lightly to moderately active adolescents (25). Thus, in moderately active controls PAL-values recommended by WHO are applicable to estimate energy requirements, whereas adolescent athletes exhibit PAL higher than WHO recommendations for adolescents and lower than recommended for adult athletes. The fact that both REE and TEE were estimated in a relatively small number of participants is a limitation of the study. However, results indicate that PAL values of adult athletes might not be applicable in adolescents and that further research is needed.

Conclusions

Results of the current study indicate that adolescent athletes engaged in competitive sports exhibit lower physical activity levels (PAL) than recommended for adult athletes by WHO and German Nutrition Society. However, mean PAL observed in adolescent athletes are higher than recommended by the WHO for lightly to moderately active adolescents. In conclusion, neither WHO recommendations for adult athletes nor for nonathletic adolescents are suitable for this special population. In conclusion, PAL values ranging from 1.75 to 2.05 (8% variation of the mean) are recommended to estimate energy requirements in adolescent athletes.
References


