Energy Balance in Young Athletes

Janice L. Thompson

Very little is known about the energy needs of young athletes. Recent studies using the doubly labeled water method have shown that the recommended dietary allowances for energy may be too high for normally active children and adolescents living in affluent societies. No studies of energy balance in young athletes have been published. Self-report dietary records of young athletes indicate that energy, carbohydrate, and select micronutrient intakes of certain athletic groups and individual athletes may be marginal or inadequate. Potential consequences of inadequate energy and nutrient intakes in young athletes include poor bone health, fatigue, limited recovery from injuries, menstrual dysfunction in female athletes, and poor performance. Studies of energy balance and nutrient status in young athletes are needed to better understand the nutritional needs of this group.

Key Words: energy intake, energy expenditure, adolescent athletes

Athletes spend a great deal of time and effort maintaining and manipulating energy balance. Depending upon the sport, athletes may be working to gain, lose, or maintain body weight. Manipulating energy balance has extremely important implications for any athlete and affects not only body weight but also one's proportion of fat-free and fat masses, carbohydrate stores, vitamin and mineral status, bone health, and menstrual status in women. Changes in the athlete's energy and nutritional status have direct implications for performance.

Young athletes are particularly affected by energy imbalance. Adolescence is a critical time for growth and development and for the establishment of life-long eating patterns. Young athletes are generally less educated about sound sport nutrition practices (1, 57), are extremely susceptible to peer influence, and are vulnerable to misinformation from a variety of sources. They also usually depend upon others for food selection; when they do make their own choices, they do not always select nutritious foods (34, 57).

It is important to stress that few well-designed studies of energy balance in young athletes have been published, limiting our current understanding of this topic. The purpose of this review is to discuss how changes in energy balance can affect the nutritional status, health, and performance of young athletes. It is hoped that this review will stimulate researchers and practitioners to study energy balance and its

---

Janice Thompson is with the Department of Health Promotion and Kinesiology, The University of North Carolina at Charlotte, 9201 University City Blvd., Charlotte, NC 28223-0001.
impact on the health and performance of young athletes and to publish data that provide insight into the energy demands of a variety of sports.

For the purposes of this review, young athletes are considered to be individuals younger than 19 years of age. Because there is not a large body of information regarding energy balance in young athletes, in certain instances select studies of college-aged athletes were also included.

**Energy Balance**

Energy balance can be defined as the state when energy intake is equal to energy expenditure. A failure to match energy intake with energy expenditure results in energy imbalance, as described below:

- If energy intake is greater than energy expenditure, the individual is in a state of positive energy balance.
- If energy intake is less than energy expenditure, the individual is in a state of negative energy balance.

Positive energy balance results in weight gain and is the desired state for growth and development in young individuals. Negative energy balance results in weight loss and is the desired state when one is attempting to lose body weight.

**How Do We Estimate Energy Balance?**

A number of techniques are used to estimate energy balance. A crude but inexpensive estimate is body weight. A stable body weight over time indicates that one is in energy balance. Assessing energy intake using diet recalls or records and comparing these values to energy expenditure estimated using activity diaries or questionnaires is another way to determine energy balance. These methods are frequently used in research and in field situations due to their convenience. While self-report data are easy to obtain and analyze, they are fraught with errors (58), limiting the accuracy of the energy balance estimates. While dietary intake records of athletes suggest that energy intakes are inadequate to match energy expenditure (15, 47), there are data to indicate that both young people (4, 13) and adult athletes underreport energy intake (21, 59). This frequent underreporting of energy intake has important implications for using diet records as a tool to study and counsel young athletes.

More accurate methods of estimating energy balance include the nitrogen balance and doubly labeled water techniques. Nitrogen balance is both time- and labor-intensive for the subjects and researchers, and the doubly labeled water technique is expensive and requires highly specialized equipment. Despite these limitations, both methods are accurate and useful for assessing energy balance in young and older athletes.

**Energy Needs of Young Athletes**

The energy needs of young athletes depend upon the athlete’s developmental stage and thus his or her age. No studies measuring the energy needs of young athletes were found in the literature. The recommended dietary allowances (RDA) for energy and protein intakes have been established for regularly active children (49) and are reported in Table 1.
Table 1 The Recommended Dietary Allowances (RDA) for Energy and Protein for Young Individuals

<table>
<thead>
<tr>
<th>Group</th>
<th>Age (years)</th>
<th>Energy intake (kcal·kg BW⁻¹·day⁻¹)</th>
<th>Protein intake (g·kg BW⁻¹·day⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Children</td>
<td>3–6</td>
<td>80–100</td>
<td>1.2–1.75</td>
</tr>
<tr>
<td></td>
<td>7–10</td>
<td>70</td>
<td>1.0–1.5</td>
</tr>
<tr>
<td>Males</td>
<td>11–14</td>
<td>55</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>15–18</td>
<td>45</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>19–24</td>
<td>40</td>
<td>0.8</td>
</tr>
<tr>
<td>Females</td>
<td>11–14</td>
<td>47</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>15–18</td>
<td>40</td>
<td>0.8</td>
</tr>
<tr>
<td></td>
<td>19–24</td>
<td>38</td>
<td>0.8</td>
</tr>
</tbody>
</table>


Maintaining the appropriate balance between energy and protein intakes is critical for the growth and development of young athletes and nonathletes. When energy intake is insufficient to meet energy needs, it is difficult to maintain protein (i.e., nitrogen) balance when the RDA for protein is consumed (68). Studies of young adult strength and endurance athletes illustrate that these active individuals have protein needs as high as two times the current RDA for protein (30, 64, 65). Because young athletes need to meet the demands of growth and activity, they must understand that depriving themselves of energy will retard growth and development and can be detrimental to training and performance.

What Effect Does Physical Training Have on the Energy Needs of Young People?

Because there are few studies of young athletes' energy needs, it is difficult to state with confidence the effects of exercise and training on energy balance in young people. It is well-recognized that adult athletes have higher energy and protein needs than sedentary adults. Whereas the energy needs of sedentary adults are approximately 35 kcal · kg⁻¹·BW (or 1.2 to 1.5 times the basal metabolic rate, or BMR), it is recommended that adult athletes consume 40–50 kcal · kg⁻¹·BW (or 1.8 to 2.2 times BMR). Westerterp and Saris (69) reported that rigorous training results in an energy expenditure 2.8 to 3.5 times BMR. Energy expenditures as high as 4.5 and 4.7 times BMR have been reported for the Tour de France and for Arctic explorers, respectively. These types of activities demand that athletes consume between 100 and 118 kcal · kg⁻¹ to meet energy needs.

Measures of total daily energy expenditure in children and adolescents using doubly labeled water have been performed (4, 13, 23, 29, 39). These studies included both sedentary and normally active subjects, but none included trained athletes. Black et al. (12) summarized the findings of these studies in which BMR was
directly measured, and some of these results are included in Table 2. The values in Table 2, measured using doubly labeled water, differ from the RDAs for energy listed in Table 1. This is most likely due to the different methodologies and subject populations upon which the results were obtained. The values reported in Table 2, although representing relatively few subjects, provide a general guide to energy requirements in young people living in affluent societies (12).

From studies of adult athletes, one can theorize that energy and nutrient needs increase with exercise training in young athletes. Young athletes not only need to meet the demands of daily living and physical training, but they also need energy to support growth and development, cope with competition-related stress (both physical and emotional), enhance recovery from injury, and maintain normal menstrual status (in female athletes).

Two groups of investigators studied the effects of exercise training on energy balance in sedentary boys and girls. Blaak et al. (11) reported an increase in total daily energy expenditure in obese boys age 10 to 11 years. The training consisted of 4 weeks of cycling exercise, with training sessions performed 5 days per week for 45 min per session. Exercise intensity ranged from 55 to 67% of maximal oxygen uptake. Total daily energy expenditure increased 12% from 2,474 kcal · day⁻¹ to 2,775 kcal · day⁻¹ (or from 1.6 times to 1.75 times RMR). Expressed per kilogram of body weight, total daily energy expenditure increased from 47.4 to 52.7 kcal · kg⁻¹. Elyakov et al. (22) reported that the total daily energy expenditure of formerly sedentary girls (age 15–17 years) was 15% higher than a sedentary control group after 5 weeks of endurance-type training performed 5 days per week. Exercise duration and intensity were not reported. Total daily energy expenditure in this study was 2,092 kcal · day⁻¹ or 34.5 kcal · kg⁻¹ for the trained subjects, and 1,815 kcal · day⁻¹ or 32.2 kcal · kg⁻¹ for the sedentary subjects. Values for BMR or RMR were

### Table 2 Energy Expenditure of Children Measured Using the Doubly Labeled Water Method

<table>
<thead>
<tr>
<th>Subjects</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>TDEE (kcal-day⁻¹)</th>
<th>TDEE (kcal·kg⁻¹)</th>
<th>Times BMR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n = 17</td>
<td>7–10</td>
<td>126.0</td>
<td>27.4</td>
<td>1,672</td>
<td>61.7</td>
<td>1.67</td>
</tr>
<tr>
<td>n = 28</td>
<td>11–14</td>
<td>161.0</td>
<td>67.5</td>
<td>2,700</td>
<td>43.3</td>
<td>1.70</td>
</tr>
<tr>
<td>n = 11</td>
<td>15–18</td>
<td>161.0</td>
<td>60.6</td>
<td>2,468</td>
<td>40.9</td>
<td>1.81</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>n = 27</td>
<td>7–10</td>
<td>134.0</td>
<td>34.8</td>
<td>2,163</td>
<td>65.4</td>
<td>1.73</td>
</tr>
<tr>
<td>n = 34</td>
<td>11–14</td>
<td>162.0</td>
<td>66.8</td>
<td>3,167</td>
<td>50.8</td>
<td>1.74</td>
</tr>
<tr>
<td>n = 11</td>
<td>15–18</td>
<td>177.0</td>
<td>67.5</td>
<td>3,556</td>
<td>53.1</td>
<td>1.97</td>
</tr>
</tbody>
</table>

not reported in this study. Both studies used the doubly labeled water technique to measure total daily energy expenditure.

These training studies illustrate that with 1 hr per day of moderate-intensity endurance-type exercise, the total daily energy expenditure of formerly sedentary young people will increase at least 12%, or approximately 300 kcal · day \(^{-1}\). Loosli and Benson (40) suggested that the energy needs of a moderately active teenager may be 1,500 to 3,000 kcal · day \(^{-1}\) greater than baseline recommendations; however, this suggestion is not based on measures of energy balance in active teens.

One must be cautious when speculating about the extent to which exercise training increases energy needs and influences energy balance. Exercise training is associated with a compensatory increase in energy intake in lean adults (20), but this increase in energy intake is not seen in exercising obese adults (20, 73). It has been suggested that individuals who exercise may compensate for the increased energy expenditure due to exercise by performing more low-level activities or performing less overall activity outside of the actual exercise bout. While obese adult women involved in an exercise and weight loss program were found to decrease the amount of physical activity performed outside of exercise training (38), obese boys did not compensate for increased exercise by decreasing other daily physical activities (11). In addition, Alméras et al. (2) found that participation in regular exercise training was not associated with performing more low-level activities in a group of adult male cross-country skiers. Thus, it is unknown whether some young athletes may counterbalance the energy expended during exercise training by reducing participation in other daily activities, by increasing energy intake, or both. These issues need to be studied in young athletes.

Although the exact energy needs of young athletes have yet to be determined, it is safe to assume that young athletes’ energy requirements will be influenced by the energy demands of a sport, the athlete’s age and gender, and the potential changes in energy intake and spontaneous physical activity associated with exercise training.

How Do Young Athletes Differ From Adult Athletes?

Similar to adults, young athletes will benefit from an adequate energy intake and nutrient-balanced diet. Young athletes do have nutritional requirements that differ from those of adult athletes, however, and these differences emphasize the importance of adequate energy, protein, nutrient, and fluid intakes before, during, and after exercise in young athletes. Following is a list of ways that young athletes differ from adults; each difference will be discussed in detail in the following paragraphs:

- Young athletes have a higher recommended protein intake (per kg BW).
- Young athletes use relatively more fat as a fuel during exercise.
- The energy cost of walking and running is higher in young athletes.
- During situations of dehydration, young athletes have a faster rise in core temperature.

As shown in Table 1, the protein needs (per kilogram body weight) of young people are higher than those of sedentary adults. As with adult athletes, it is plausible that young athletes’ protein needs are higher than their less active peers in order to support the increased demands of growth, development, and physical training. There
appear to be no published studies of young athletes’ protein needs; thus, specific protein intake recommendations for young athletes cannot be made.

Studies of young individuals performing exercise have shown that fat utilization and the energy cost of walking and running are different in young individuals compared to adults performing similar exercise. Young people have higher free glycerol levels in the blood (42, 44), increased free fatty acid uptake (16), and lower respiratory exchange ratios during exercise (44), indicating greater fat utilization than adults. This greater use of fat as a fuel during exercise does not increase the dietary recommendation for fat, however (6). Haymes et al. (32) reported a higher energy cost for walking and running in young girls as compared to women. The higher energy cost during these activities would be expected to increase total daily energy needs for athletic children and adolescents performing a significant amount of walking and running.

Bar-Or et al. (5) showed that young people experience a significantly greater rise in core temperature for the same level of dehydration in an adult. This indicates that children thermoregulate less efficiently than adults, which is most likely due to children having a slower sweating rate (45), higher ratio of surface area to body mass (which leads to greater heat exchange with the environment), and increased metabolic heat production (due to increased energy expenditure during walking and running). These findings emphasize the need for enforcing fluid intake in children and adolescents prior to, during, and following exercise.

**Reported Energy and Nutrient Intakes in Young Athletes**

Some researchers have attempted to document young athletes’ energy and nutrient intakes. All published studies have relied on self-report dietary records, which means the reported values are only as accurate as the subject’s ability to correctly record dietary intake. Studies in young athletes have shown consistent patterns of inadequate intakes of energy and specific nutrients in certain athletic groups. Table 3 summarizes the findings of energy intake studies in young athletes. It would be inappropriate to discount all findings of energy intake studies, because dietary records can provide important information for the athlete, coach, and researcher. However, improved methods of dietary assessment need to be developed to provide convincing evidence of energy and nutrient imbalances in athletes.

Many of the athletes in the studies summarized in Table 3 reported energy intakes lower than recommended (using the RDA as a reference). Recent findings of doubly labeled water (DLW) studies in young people suggest that the RDA may overpredict energy needs in this group (12). Since actual energy needs of young athletes have not been determined, and total daily energy expenditure was not measured in these studies, it is not possible to conclude whether the energy intakes reported in Table 3 are adequate to meet energy expenditure. Many of the athletes studied reported energy intakes below both the RDA and the DLW values reported for nonathletic subjects. As previously discussed, young people have been shown to underreport energy intakes (4, 13), and the seemingly inadequate intakes of some athletes may be due to errors made while recording diet records. However, it is well-recognized that specific groups of athletes (gymnasts, dancers, distance runners, and wrestlers) regularly restrict energy intake in order to meet the body weight and image demands of their sport. Body image may play a significant role in the athlete’s
Table 3  Self-Reported Energy Intakes of Young Athletes

<table>
<thead>
<tr>
<th>References</th>
<th>Sport</th>
<th>Number of subjects</th>
<th>Age (years)</th>
<th>Height (cm)</th>
<th>Weight (kg)</th>
<th>Energy intake (kcal · day⁻¹)</th>
<th>(kcal · kg⁻¹)</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Gymnastics</td>
<td>29 7-10</td>
<td>134.9</td>
<td>30.6</td>
<td>1651</td>
<td>53.9</td>
<td></td>
</tr>
<tr>
<td>7,8,25,26,41,74</td>
<td></td>
<td>240 11-14</td>
<td>146.7</td>
<td>36.8</td>
<td>1793</td>
<td>48.3</td>
<td></td>
</tr>
<tr>
<td>24,25,28,35,46</td>
<td></td>
<td>56 15-18</td>
<td>160.6</td>
<td>51.0</td>
<td>1789</td>
<td>35.6</td>
<td></td>
</tr>
<tr>
<td>8,25,31,74</td>
<td>Swimming</td>
<td>100 11-14</td>
<td>156.5</td>
<td>47.22</td>
<td>2069</td>
<td>45.1</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td>22 15-18</td>
<td>—</td>
<td>58.2</td>
<td>3573</td>
<td>61.4</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Volleyball</td>
<td>26 13-17</td>
<td>—</td>
<td>—</td>
<td>1799</td>
<td>—</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Dance</td>
<td>92 12-17</td>
<td>160.2</td>
<td>46.8</td>
<td>1890</td>
<td>40.8</td>
<td></td>
</tr>
<tr>
<td>Males</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>31</td>
<td>Swimming</td>
<td>9 11-14</td>
<td>—</td>
<td>56.4</td>
<td>3072</td>
<td>55.0</td>
<td></td>
</tr>
<tr>
<td>10,25</td>
<td></td>
<td>42 15-18</td>
<td>182.0</td>
<td>75.1</td>
<td>4537</td>
<td>60.2</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>Running</td>
<td>4 7-10</td>
<td>—</td>
<td>—</td>
<td>1952</td>
<td>65.0</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td></td>
<td>14 11-14</td>
<td>—</td>
<td>—</td>
<td>2541</td>
<td>66.0</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td></td>
<td>4 15-18</td>
<td>—</td>
<td>—</td>
<td>2736</td>
<td>50.0</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td>Wrestling</td>
<td>4 7-10</td>
<td>—</td>
<td>—</td>
<td>1892</td>
<td>64.0</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td></td>
<td>50 11-14</td>
<td>—</td>
<td>—</td>
<td>2459</td>
<td>53.0</td>
<td></td>
</tr>
<tr>
<td>56</td>
<td></td>
<td>20 15-18</td>
<td>—</td>
<td>—</td>
<td>2703</td>
<td>44.0</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Football</td>
<td>46 11-14</td>
<td>—</td>
<td>60.9</td>
<td>2523</td>
<td>41.4</td>
<td></td>
</tr>
<tr>
<td>33</td>
<td></td>
<td>88 15-18</td>
<td>—</td>
<td>75.9</td>
<td>3365</td>
<td>44.3</td>
<td></td>
</tr>
</tbody>
</table>

*Indicates value not reported.

ability to accurately report energy intake, as Edwards et al. (21) found a positive relationship between distorted body image and underreporting of energy intake in college-aged athletes. Self-reported energy intakes in young athletes need to be validated using DLW or nitrogen balance to determine the extent to which young athletes meet their energy needs.

The high incidence of eating disorders, menstrual dysfunction, and use of pathogenic weight control practices reported by young athletes (19, 63) suggests that many athletes do not meet the energy demands of their highly active lifestyles. Longitudinal studies of vigorous exercise training and its impact on energy balance need to be completed to determine how the dietary practices of young athletes affect growth, health, and performance.

**Consequences of Negative Energy Balance**

How will failure to meet energy needs affect the health of the young athlete? The following consequences of chronic negative energy balance will be reviewed in detail:
- Short stature and delayed puberty
- Nutrient deficiencies and dehydration
- Menstrual irregularities
- Poor bone health
- Increased incidence of injuries
- Increased risk for developing eating disorders

Pugliese et al. (51) studied children who restricted energy intake due to a fear of obesity. These children exhibited symptoms of slow stature, slow growth, and delayed puberty. None of these subjects exhibited clinical signs of anorexia nervosa, and none were athletes. However, these children’s responses to restricted energy intake may be similar to the responses of some young athletes. Sports such as gymnastics, ballet dancing, figure skating, body building, and wrestling have been identified as encouraging marginal energy intakes in order to meet the low body weight, small stature, and unique body image criteria inherent in these sports (55). Energy restriction has been shown to inhibit the production of growth factors critical to normal growth and development. Smith et al. (61) found that 6 days of energy restriction (35 kcal·kg⁻¹·day⁻¹) in children ages 8 to 11 years resulted in a negative nitrogen balance and decreases in circulating levels of insulinlike growth factor-I (IGF-I) and IGF binding protein-3 (IGFBP3). The authors suggested that these changes in IGF-I and IGFBP3 may indicate a growth hormone–resistant state, which would hinder normal growth and development with long-term energy restriction.

In reviewing the literature, it becomes quite clear that some young athletes report consuming inadequate energy intakes, while others report energy intakes well above the recommended levels. The average reported values for energy intakes of male football players and some male and female swimmers are adequate (10, 33), but many individual athletes, particularly gymnasts, dancers, and wrestlers, report inadequate energy intakes (refer to Table 3). These inadequate energy intakes are generally accompanied by marginal macro- and micronutrient intakes (7-9, 26, 31, 41, 46, 56). The nutrients most commonly reported as inadequate include carbohydrate, vitamin B₆, calcium, folate, iron, and zinc. Poor carbohydrate intakes can result in inadequate glycogen stores and premature fatigue, in addition to increasing the use of body protein stores for energy. Adequate calcium intakes are critical to maintain bone mass. Low iron intakes can impair oxygen-carrying capacity and inhibit training and performance if iron deficiency anemia results (60). Deficiencies of vitamin B₆ can limit amino acid synthesis and red blood cell production, while low folate and zinc intakes can inhibit cell growth and repair (70). Chronically marginal intakes of these nutrients could significantly impact a young athlete’s general health and athletic performance. Dehydration can also result if inadequate energy intakes are coupled with low fluid intakes.

While increasing consumption of these nutrients should help to prevent deficiencies, Telford et al. (66) found that improving iron status may not be as simple as increasing the intake of both energy and foods high in iron. These researchers studied the relationships between plasma ferritin levels (an indication of body iron stores) and select dietary variables in athletes age 16 to 25 years who were participating in a variety of sports. All athletes had normal hemoglobin, hematocrit, and red blood cell counts. Regression analyses indicated that neither total iron intake nor
meat intake contributed significantly to the variation in iron status in athletes. In addition, total energy intake was negatively correlated with iron status. The variable that best predicted iron status was the proportion of protein in the diet, suggesting that the percentage of protein in the diet (but not the total protein intake) facilitates iron absorption. These findings illustrate that there is a great deal to learn about the relationship between food intake and nutrient status in young athletes.

Menstrual dysfunction has been documented in both young and adult female athletes (37). Menstrual dysfunctions found in female athletes include subclinical ovulatory disorders, such as luteal phase deficiency and anovulation, and clinical disturbances such as oligomenorrhea and amenorrhea. The etiology of menstrual abnormalities is multifactorial. Some of the factors associated with menstrual irregularities includes stress (related to lifestyle issues and athletic performance), inadequate energy intake, low percentage of body fat, and vigorous training regimens. Researchers have suggested that the disruption or cessation of normal menstrual function is an energy-conserving mechanism for female athletes who have low energy intakes accompanied by rigorous training (48). Williams et al. (71) found that combining energy restriction with exercise training depressed LH pulse sensitivity in adult eumenorrheic female runners, suggesting that the combination of physical stress and inadequate energy intake can alter menstrual function.

The results of an intervention study by Dueck et al. (18) show that "energy drain" plays a significant role in athletic amenorrhea. These researchers helped an amenorrheic athlete normalize hormone profiles and menstruation by having the athlete decrease training from 7 to 6 days per week and increase daily energy intake by 300–400 kcal · day⁻¹. While this study was limited to one athlete, the athlete’s positive response to an attempt to balance energy is encouraging, and more interventions of this nature may help normalize menstrual function in female athletes who have menstrual irregularities.

Young female athletes and their coaches need to be educated about the negative health implications of menstrual disturbances. Contrary to popular belief, menstrual irregularities do not indicate optimal body fat or training levels. While cessation of menstruation may be viewed as convenient, it can be detrimental to bone health and may have long-term consequences resulting in infertility and other reproductive problems, impaired immune function, and an increased risk for cardiovascular diseases (17).

Some female athletes with menstrual disorders have been shown to have decreased bone mineral densities (72). The poor bone health of these athletes is most likely a combination of the effects of low calcium intakes, limited calcium absorption, and hormonal disturbances on bone metabolism. The type of exercise performed can also influence bone density. Rico et al. (52) reported that young male cyclists (mean age 16.2 years) had a total bone mass similar to sedentary controls, but the athletes had lower leg bone mineral content. Contrary to these findings, elite junior Olympic weight lifters (mean age 17.4 years) were found to have higher spine and femoral bone mineral density than a group of sedentary controls (14). This phenomenon also occurs in female athletes. Athletes participating in impact loading sports, such as gymnastics and volleyball, have been shown to have higher total and regional bone mass than swimmers and runners, and the higher bone mass in gymnasts occurs even in athletes with menstrual dysfunction (27, 53). Poor bone health in athletes can lead to a higher incidence of stress fractures (43) and related injuries.
It has also been suggested that children in general may be more prone to overuse injuries (3) than adults, indicating that training progression in young athletes should be slower than that for adults.

Many young athletes report skipping meals and intentionally restricting energy intake to meet the needs of their sport. This type of behavior can lead to more dangerous nutritional practices, such as vomiting and using laxatives and diuretics. These pathogenic weight control techniques are common among individuals with eating disorders, and the incidence of eating disorders is significantly higher in athletes than in the general population (54). In order to decrease the incidence of eating disorders and use of dangerous weight control techniques, young athletes need to be better educated regarding healthy food choices and adequate energy intake.

**Consequences of Positive Energy Balance**

If energy intake exceeds energy demands, obesity will result. Obesity in young people is often accompanied by high total fat and saturated fat intake, hypertension, and dyslipidemia, all of which increase one's risk for cardiovascular disease. While the causes of obesity are known to be multifactorial, Vuille and Mellbin (67) reported that heredity (e.g., parents' weight and height) and physical inactivity were the strongest predictors of obesity in 10-year-old girls, while appetite and environmental factors (e.g., parents' work, social class, and child's birth order) were the best predictors of obesity in boys at the same age.

Participation in sports and increased physical activity are frequently recommended for treating childhood obesity. Energy-restricted diets are generally not recommended for children who are growing. Jacobsen et al. (36) reported the results of a program designed for obese adolescents (mean age 11.2 years). The goals of the program were to reduce the subjects' cardiovascular disease risk by reducing fat and saturated fat intake and increasing energy expenditure through physical activity without decreasing energy intake, so that continued growth was accompanied by a slowing of weight gain. This program decreased blood pressure, total cholesterol, LDL-cholesterol, triglycerides, and body weight while allowing for normal growth. The results of this study emphasize the importance of regular physical activity and healthy eating habits to reduce the risk of cardiovascular disease in young people as well as adults.

**Summary and Conclusions**

We have little data on energy balance in young people, and no data appear to be published on energy balance in young athletes. The results from the few training studies including young people as subjects suggest that moderate-intensity, endurance-type exercise performed 1 hr · day⁻¹, 5 days · week⁻¹ by previously sedentary subjects increases energy expenditure approximately 12 to 15%, or 250 to 300 kcal · day⁻¹.

It has been suggested that active teenagers require 1,500 to 3,000 kcal · day⁻¹ more energy than is currently recommended. While this suggested increase in energy needs is similar to that reported for adult athletes, no energy balance studies have been performed to verify this suggestion. The results of DLW studies in young people indicate that the RDA for energy may be too high; thus, the energy balance of young athletes must be measured before sound recommendations can be made.
Self-report dietary records indicate that many young female athletes report marginal or inadequate energy intakes. While the average energy intakes of young male athletes appear to be adequate, certain individual male athletes also report low energy intakes. These reportedly low energy intakes are accompanied by marginal or low intakes of carbohydrate and many micronutrients.

Applications

After reviewing the literature on energy balance in young athletes, it is apparent that certain issues need to be addressed in this population. First, young athletes need to be educated about the importance of nutrition for optimizing health and performance. Many young people are vulnerable to receiving nutrition misinformation, and they are also strongly influenced by the opinions, suggestions, and actions of peers, coaches, and parents.

Second, better nutrient assessment tools need to be developed and used when studying dietary intakes of athletes. While the DLW technique accurately indicates general energy needs over 2 to 3 weeks, it does not reflect the athlete’s intake of macro- and micronutrients. My personal experiences with young athletes verify that certain athletes have inadequate intakes of energy and various nutrients. These suspicions about nutritional inadequacies are supported by the relatively high incidence of eating disorders (62), use of pathogenic weight control techniques, and menstrual dysfunction in female athletes. Unfortunately, many of the assessment tools currently used are not accurate enough to address the prevalence of true nutritional deficiencies in young athletes or to identify direct cause-and-effect between nutritional intakes, health, and performance.

Finally, we need to work with athletes who are at risk for energy imbalance problems to help them meet both their performance goals and their goals for maintaining healthy eating habits. We must not, however, lose sight of the requirements of the sports in which these athletes are involved. To establish and maintain credibility with these athletes, we must keep an open mind and find ways that these athletes can consume healthy diets and also meet the demands of their sport.

References

44. Martinez, L.R., and E.M. Haymes. Substrate utilization during treadmill running in


Manuscript received: October 24, 1997
Accepted for publication: January 15, 1998