Profiling the Diet and Body Composition of Subelite Adolescent Rhythmic Gymnasts

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The aim of this study was to investigate the body composition and dietary intake of competitive club-level rhythmic gymnasts, who represent the larger cohort of the sport’s practitioners. Fifty-five rhythmic gymnasts and 55 nonathlete females (13–19 years of age) were seen individually to collect a dietary recall and to take anthropometric data and bioelectric-impedance analysis. Gymnasts had lower body-mass index and lesser skinfold thickness, although middle arm-muscle circumference was similar in the 2 groups. Gymnasts had lower body-fat measures but normal levels of fat-free mass (FFM) and body-cellular mass. Gymnasts had better dietary habits than the age-matched controls. Low levels of calcium, phosphorous, iron, and zinc and a disparity between reported energy intake and estimated energy requirement were observed in both groups.

Rhythmic gymnastics is a competitive sport requiring speed, power, gracefulness, and aesthetic appeal—both physical shape and strength are necessary. Leanness is particularly valued because a gymnast’s success is a function of either technical performance or appearance. For this reason, leanness also represents an important selection factor. The competitors are very young, and adolescence is the period of intensive training and selection of elite gymnasts. Training is characterized by brief periods of high-energy activity, with alternating periods of resting or low-intensity and stretching exercises. As a consequence, the average hourly energy expenditure is not as elevated as one might think.

High-level gymnasts are considered to be at risk for inadequate nutrition because of their tendency to adhere to inappropriate diets to achieve leanness or to prevent fattening (6).

Scarce nutritional knowledge and bad dietary practice are frequent among adolescents, namely high energy and lipid intake, low dietary content of fiber and iron, and low energy supply at breakfast (4,30). Moreover, the lack of sound nutritional practices has also been observed in adolescents engaged in high-level

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Adequate nutrition in adolescent athletes is very important; their dietary intake must provide the biological needs for body growth and body maintenance, as well as the extra energy and nutrient intake required for physical activity. Rhythmic gymnastics is one of the disciplines in which there is a great pressure for leanness; therefore, nutritional assessment and intervention is of basic importance (36).

The combination of food restriction and intensive training is thought to have a profound effect on the release of gonadotropins, leading to delayed puberty and menstrual disorders in adolescent athletes (26). Rhythmic gymnastics involve girls practicing intense athletic training at a very young age, which is a possible cause of delayed menarche because of the effect that intense exercise before puberty can exert on the gonadal axis (3,26). Theintz et al. (40) claimed that intense physical training represents a chronic stress capable of attenuating growth. Georgopulos et al. (16) reported a delay in adolescent growth spurts in female rhythmic gymnasts. They found that psychological stress and intense physical activity can have a profound effect on growth and skeletal maturation, but they also affirmed that the rhythmic gymnasts compensate for their loss of pubertal growth spurts with late accelerations of growth toward the end of puberty.

More recent studies by Loucks et al. (27) highlight the fact that the energy deficit that is often observed in female athletes involved in aesthetic sports is the main cause of menstrual disorders. These authors affirmed that energy deficiency impairs performance, growth, and health. They also stated that menstrual irregularities in female athletes are caused by low energy availability (defined as dietary energy intake minus exercise energy expenditure) and not by the stress resulting from intensive exercising (27,35).

Competition is also thought to facilitate the onset of eating disorders, especially in sport disciplines in which appearance, lean body shape, and low body weight are emphasized (23,42).

As a result of these factors, there are concerns about the nutrition of rhythmic gymnastics; for example, intensive physical training or changes in dietary habits and nutritional status can negatively affect immune response mechanisms and, thus, might increase the risk of infections.

In a previous study conducted on 20 elite rhythmic gymnasts on the national Italian team, dietary intake was relatively low in calories but had a correct distribution of the daily energy intake among the macronutrients, a low content of cholesterol and saturated fats, and a high intake of vitamin A and fiber compared with nonathletic age-matched females (8). Deficient dietary intakes of calcium, iron, and zinc were detected, however, in both groups (8). The gymnasts included were elite athletes, so the question arises as to whether the same characteristics might be extended to the general population of gymnasts practicing this discipline. For this reason, our study investigated body composition, dietary intake, and the incidence of infections in competitive subelite club-level rhythmic gymnasts and age-matched nonathlete controls.
Materials and Methods

Participants

The study included 110 Italian adolescent females: 55 rhythmic gymnasts and 55 nonathlete age-matched females.

The athletes were recruited from clubs affiliated with the Italian Federation of Gymnastics. All were subelite competitive gymnasts; gymnasts engaged in international competition with the national Italian team were excluded. The participants were studied during their regular training sessions, far from important competitions.

Nonathlete female adolescents were randomly selected from junior and senior high school students to form an age-matched group. The control participants performed less than 3 hr/week of general physical activity, namely, jogging, fitness, or dance (hip-hop, jazz). None of them were involved in national-level competitive sport activities.

Dietary Assessment

Each participant was seen individually by a registered dietitian to collect anthropometric measurements and a 3-day food record for nutrient-intake assessment. The 3-day recalls were collected by interviews during which the participants were given a color photo exhibit of commonly consumed foods and serving sizes to help them estimate the actual amounts of consumed food. In order to relate dietary-intake assessment to intense physical activity, we excluded evaluation of dietary habits outside of regular training. As a result, Sundays and holidays were excluded. The dietary composition was assessed using the tables of food composition provided by the Italian National Institute of Nutrition (7). The total energy and nutrients intake and distribution among meals were examined. For each studied nutrient, daily intake was calculated as the average of the 3-day food records. Results of the nutrient intake were compared with the Italian recommendations by gender and age (38).

Estimated energy requirements were calculated using the Harris-Benedict equation (18) as a measure of basal metabolic rate plus the energy expenditure for physical activity. We assumed an activity factor of 1.6 for the gymnasts and 1.4 for the controls.

Anthropometry

Anthropometric measurements were made early in the afternoon, before the beginning of the training session. Body weight and height were measured with participants wearing light clothing and without shoes. Body-mass index was calculated as body weight/height$^2$ and expressed as kg/m$^2$.

Plicometry was performed using Holtain’s skinfold callipers. Skinfold thickness was measured at four specific sites: triceps, biceps, subscapular, and iliac (5).

Body circumferences were measured at five selected sites using a tape measure: middle arm, forearm, chest, waist, and hip (20). Skinfolds and circumferences were registered as the mean of two consecutive measurements.
Triceps skinfold thickness and middle arm measurements were used to calculate the middle arm-muscle circumference using the following formula: middle arm-muscle circumference = middle arm – \( \pi \times \) triceps skinfold thickness.

Percentage body fat was calculated using the Siri equation (37).

**Bioelectric-Impedance Vector Analysis**

Bioelectric-impedance vector analysis (BIVA) was conducted on the rhythmic gymnasts using a bioelectrical impedance analyzer (BIA/STA, Akern, Florence, Italy) with a distal tetrapolar technique, delivering an excitation current at 50 kHz (34). BIVA parameters were measured in duplicate. Gymnasts’ BIVA data were compared with the age- and sex-matched controls (10,34). BIVA does not measure body composition directly, but it gives two bioelectric parameters: body resistance and reactance. Resistance (R, \( \Omega \)) is the body’s opposition to the flow of an alternating electrical current, and it is inversely related to the water and electrolyte content of tissue. Reactance (Xc, \( \Omega \)) is related to the capacitance properties of the cell membrane, and variation can occur depending on its integrity, function, and composition (25). The impedance vector (Z) is a combination of R and Xc across tissues. The arc tangent of Xc/R is called the phase angle, which is a measure derived from the relation between the direct measures of resistance and reactance (1). Total-body water (TBW) is estimated from the measurement of whole-body impedance (TBW = \( \rho h^2/Z \), where \( \rho \) is resistivity and h is standing height). Fat-free mass (FFM) and fat mass (FM) are calculated from TBW values, based on the concept that the water content of FFM is constant and body fat is anhydrous: FFM = TBW/0.73; FM = body weight – FFM (41).

The RXc graph method consists of a bivariate analysis of the measured electric properties of the body and provides a qualitative estimation of hydration and cellular mass by comparison with a reference population (34). Namely, the impedance vector analysis is plotted on the RXc graph reporting sex-specific 50%, 75%, and 95% tolerance ellipses of the healthy population. The day-to-day coefficient of variation of BIVA measurement is 1%, and the interoperator variability averaged 2% (34). According to clinical validation studies, vectors falling out of the 75% tolerance ellipse indicate an abnormal tissue impedance, which is interpreted and ranked following the two directions of major and minor axes of tolerance ellipses: (a) Vector displacements along the major axis of tolerance ellipses indicate progressive changes in body water (i.e., dehydration out of the upper pole and hyperhydration out of the lower pole), (b) vector displacements along the minor axis indicate changes in body-cell mass, and (c) different trajectories indicate combined changes in both hydration and body-cell mass.

**Prospective Evaluation of Infectious Events**

To detect whether gymnasts were at a higher risk of infections, all participants were followed for a period of 35 weeks to observe the occurrence of infections. Events were registered weekly by the gymnasts’ coaches and the controls’ teachers. The participants had to choose among various options to define the consequences related to an event, such as medical visit, use of drugs or other kind of therapies, or days
of absence from school or from training. Events that caused at least one of those consequences were considered significant and included in the statistical analysis.

The study was approved by the ethics committee of the University Hospital of Pisa. Written informed consent was obtained from the parents of the participants.

**Statistical Analysis**

Data were analyzed using an NCSS statistical package (Hintze J.L., Kaysville, UT). Descriptive data are expressed as $M \pm SD$. Statistical evaluation was performed by the Student’s $t$ for paired and unpaired data. Differences were considered statistically significant when $p < .05$.

**Results**

**Dietary Assessment**

Figures 1 and 2 show the results of the dietary-habits analysis. The reported energy intake, normalized for body weight, was similar between athletes and controls ($28.8 \pm 10.8$ vs. $28.2 \pm 8.7$ kcal/kg body weight). The difference between the recommended energy intake and the estimated energy requirements was higher in gymnasts than in controls ($-501$ vs. $-257$ kcal/day).

The distribution of the daily energy intake among the macronutrients showed a higher energy intake from carbohydrates ($54.9\% \pm 5.7\%$ vs. $49.5\% \pm 5.9\%$,

![Figure 1](image-url) — Percentage distribution of the daily energy intake among macronutrients in the rhythmic gymnasts (white bars) and controls (black bars). *$p < .05$. **$p < .001$.}
p < .001) and a lower energy intake from lipids (28.0% ± 6.0% vs. 34.6% ± 5.0%, p < .001) in the gymnasts; the recommended percentages for a well-balanced diet were met.

Protein intake, normalized for body weight, was 1.21 ± 0.4 g/kg in gymnasts and 1.12 ± 0.4 g/kg in controls, and it approximated the recommended dietary allowances (RDAs) for weight, age, and sex. Both gymnasts and controls properly consumed more complex carbohydrates than simple sugars, and no differences emerged between the two groups. The intake of saturated fatty acids and cholesterol were significantly higher in controls.

Fiber intake was similar in the two groups (14.1 ± 4.7 g vs. 13.6 ± 5.0 g), but it only covered the recommended minimum amount of 10 g/1,000 kcal in the gymnast group.

The dietary content of vitamins was similar in the two groups, except for vitamin B1 and vitamin B2, which were lower in the controls. Figure 2 shows that vitamin intake approximated 100% of the RDA values in the gymnasts. Calcium, phosphorus, zinc, and iron intakes were below the RDAs (Figure 2) in both groups.

There was no difference between the two groups for daily distribution of energy intake among the different meals. Energy from snacks was above the recommended percentage but at the expense of breakfast, which should represent 20–25% of total energy intake, especially in young athletes.

**Figure 2**—Mean dietary intakes of minerals and vitamins, expressed as percentage change from the RDA values, in the rhythmic gymnasts (white bars) and controls (black bars).
The reported water intake did not cover the recommended daily requirement of 1 ml/kcal in either group, and it was apparently insufficient to satisfy the hydration needs of the gymnasts.

**Anthropometry**

Anthropometric characteristics of rhythmic gymnasts and control participants are reported in Table 1. Gymnasts had lower body weight, body-mass index, body circumferences, and skinfold thicknesses. No differences were observed for height or middle arm-muscle circumference. Body-fat mass, as detected by plicometry, was significantly lower in the gymnasts.

**BIVA**

BIVA in rhythmic gymnasts showed phase-angle values in the normal range for age and sex (6.7° ± 0.5°; expected values 6–7°). Body-cell mass (22.1 ± 2.7 kg), representing the metabolically active part of the body responsible for oxygen and energy consumption, was above the theoretical minimal value calculated for each participant (18.5 ± 1.7 kg, \( p < .0001 \)). The percentage of FFM (79.6% ± 5.0%) was in the normal range for sex and age (FFM expected values 78–80%). TBW was lower than expected (59.7% ± 4.9%, expected values > 62%), suggesting an alteration of the hydration state. Most of the impedance vectors obtained for each gymnast fell on the upper left of the ellipses on the RXc graph, thus suggesting a

<table>
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<tr>
<th>Parameters</th>
<th>Rhythmic gymnasts</th>
<th>Controls</th>
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<td>Age (years)</td>
<td>15.2 ± 2.2</td>
<td>15.0 ± 2.0</td>
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<td>Height (m)</td>
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<td>Body weight (kg)</td>
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<td>Body-mass index (kg/m(^2))</td>
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<td>&lt;.001</td>
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<td>Middle arm circumference (cm)</td>
<td>20.8 ±1.2</td>
<td>24.7 ± 2.7</td>
<td>&lt;.001</td>
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<tr>
<td>Forearm circumference (cm)</td>
<td>20.7 ± 1.4</td>
<td>22.0 ± 1.9</td>
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<td>Chest circumference (cm)</td>
<td>81.3 ± 5.8</td>
<td>86.4 ± 7.9</td>
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<tr>
<td>Waist circumference (cm)</td>
<td>66.8 ± 4.5</td>
<td>70.1 ± 6.5</td>
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<tr>
<td>Hip circumference (cm)</td>
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<td>Triceps skinfold thickness (cm)</td>
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<td>Middle arm-muscle circumference (mm)</td>
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<td>ns</td>
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<tr>
<td>Fat mass (%)</td>
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<td>19.1 ± 3.2</td>
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<td>Age at menarche (years)</td>
<td>13.3 ± 1.3</td>
<td>12.2 ± 1.2</td>
<td>&lt;.001</td>
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</table>
good shape and fitness level, but 26% of them fell between the 75% and the 95% tolerance ellipses, and 17% fell out of the upper pole, indicating a dehydration state. FM, as assessed by BIVA, was in the normal range (20.4 ± 5.0 kg, expected values 16–20%) but higher than the FM value derived from the Siri equation (Table 1).

Of the gymnasts, 55.3% reported regular menses, and 85.7% of the controls reported regular menses; 2% of the gymnasts reported secondary amenorrhea, and 4% of the gymnasts and 7% of the controls reported menstrual irregularities (defined as a menstrual-cycle duration greater than 36 days). The mean age of menarche was significantly higher in the gymnasts (13.3 ± 1.3 vs. 12.2 ± 1.2 years, \( p < .001 \)). The gymnasts who had not reached menarche had a lower percentage body fat (14.7 ± 2.6 vs. 17.8 ± 2.6, \( p < .001 \)).

**Infections**

There was no difference in the incidence of infections between the two groups. The number of events per participant was 1.25 in the gymnasts and 1.11 in the controls. At the end of the observation period, 14.3% of the gymnasts and 13.9% of the controls did not report any fever events. The sport-training sessions missed by controls were twice as many as by the gymnasts (11.9 vs. 5.5 days), but absences from school as a result of these events were similar in the two groups (347 and 324 days, respectively).

**Discussion**

This study showed similar dietary habits between gymnasts and age-matched controls with a similar protein intake, even though gymnasts showed more consumption of complex carbohydrates and a lower intake of saturated fats and cholesterol than the controls did. The reported energy intake was lower than the estimated energy requirement in gymnasts.

Differences between energy expenditure and energy intake have already been reported in female athletes (9,19), especially in elite gymnasts (8,11,13,21). Energy underreporting or overestimation of energy requirements could explain this difference. The daily-energy-intake distribution among the macronutrients, however, was greater in the gymnasts when it fulfilled the recommended percentages for a well-balanced diet. These data are in keeping with the results of previous investigations of elite gymnasts (8,9). Saturated-lipids and cholesterol intake were significantly higher in the controls, thus confirming the better dietary habits of the gymnasts, who also showed an adequate fiber intake.

According to the literature, the reported calcium, iron, zinc, and phosphorus intakes were less than 100% of the RDA (29,32). Therefore, more attention should be given to mineral intake in adolescent females to meet the demands of both growth and sport activity. All reported vitamin intakes, except for niacin, were above the RDA in the gymnasts, but there was a reduced thiamine, riboflavin, and niacin intake in the controls, probably because of a lower consumption level of meat and dairy products.

Different from elite gymnasts (8), but in accordance with the literature (31), we found a low energy intake at breakfast and a higher energy intake from snacks in both groups, a typical aspect of modern adolescents’ dietary habits. Gymnasts
involved in this study lived with their own families and attended school as any other age-matched students (with the important difference that they spend many hours per week in intensive training), so they are more likely induced to follow typical adolescent behavior. As we observed from their dietary-habits analysis, they are positively influenced by being involved in sport, but less so than elite rhythmic gymnasts, who represent a very select group of female athletes. These select athletes often live far from home for long periods for intensive training, and, generally, they do not attend public school but are individually instructed.

Another aspect that emerged from the dietary analysis was scarce fluids intake. This is particularly worrying for the gymnasts, who could be unable to satisfy the extra demands of intensive training.

BIVA showed phase-angle values within the normal distribution for age and sex. Phase angle has been interpreted as an indicator of membrane integrity and water distribution between the intra- and extracellular compartments. It is also used as an estimate of body-cell mass, and, for this reason, it has been used as a nutritional indicator in adults and children (28,33). Our study showed phase-angle values in the normal range, indicating good body composition and nutritional status. FFM, which reflects mainly muscle and internal-organs mass (25,35), was in the normal range for sex and age. Body-cell mass, representing the metabolically active part of the body responsible for oxygen and energy consumption, was above the theoretical minimal value calculated for each participant. These results are in keeping with leanness, health, fitness, and good shape in the gymnasts (24,34). In this group, the percentage of FM, as assessed by BIVA, was normal, but it was lower than in controls using the Siri equation from anthropometry measures. To better understand whether this discrepancy is a result of an overestimation of BIVA or an underestimation of anthropometric measurements, we should have also had data of FM from BIVA for the control group to make a comparison. Unfortunately, we did not perform BIVA in the control group, and we only compared gymnasts’ BIVA with the age- and sex-matched general population. This can be considered a limitation of the study.

BIVA showed a reduction of TBW, which is considered an important parameter to predict changes in nutritional status, both in adults and in children (12,41). It is known that water plays a central role in nutrient transport, waste removal, maintenance of cell volume, and thermal regulation. Thus, TBW represents a useful body-composition parameter per se, but measurements of TBW can also be useful for FFM and FM determination, based on the concept that the water content of FFM is constant and body fat is anhydrous. We found that FFM was in the reference range, so the reduction of TBW could be linked to an insufficient fluid intake, observed by the dietary assessment, or to a greater requirement because of intensive training. Thus, a regular measurement of total-body water in these athletes could be useful to monitor fluid status and body composition and to detect early negative changes.

The fact that rhythmic gymnasts are also required to keep a low body weight to maintain a favorable shape for high-level performance is thought to contribute to the risk of developing poor eating habits that, in turn, could lead to malnutrition or eating disorders (23,42).

Body composition, low body FM in particular, has also been used to explain the delayed menarche and menstrual-cycle irregularities among elite athletes (14).
Previous studies suggested a minimal level of 17% body fat for the onset of menses and maintenance of a normal cycle (14). In our study, FM in the gymnasts with regular menses was 17.8% on average, and for nonmenstruating gymnasts was under the critical value of 17%, according to previous findings. The lower percentage of FM in the premenarcheal gymnasts could also be a result of a delayed maturation, because FM increases as a result of maturation. Thus, low FM could represent the effect and not the cause of the delayed menarche.

Recent studies have suggested that delayed menarche might also be a result of environmental, psychological, or genetic factors (2,15,17,22). In particular, rhythmic gymnasts performing under conditions of high intensity are exposed to particularly high levels of psychological stress and intense physical training, and these factors can have deleterious effects on growth, skeletal maturation, and pubertal development. On the other hand, Georgupolos et al. confirmed these findings but emphasized that the delay in skeletal maturation and pubertal development observed in female rhythmic gymnasts is compensated for by an acceleration of growth toward the end of puberty, and, despite the delay in skeletal maturation, genetic predisposition for growth is not only preserved but exceeded (16).

Follow-up studies would be necessary to define the role of each factor possibly involved. Loucks et al. and Redman et al. claimed that menstrual disorders are the result of an energy deficit from insufficient carbohydrate intake frequently observed in female athletes engaged in aesthetic sports (27,35). We found that gymnasts’ energy intake was lower than the estimated energy requirement, even if the reported energy intake normalized by body weight was similar in gymnasts and controls. In any case, the findings of Loucks et al. are very important because they encourage us to pay more attention to female athletes’ dietary habits and to develop effective dietary interventions suitable and acceptable to the athletes.

The studied adolescent population was also followed for 35 weeks to detect infectious events. No difference emerged in the incidence of these events between the two groups, and there was no difference in the number of school days missed. The controls had twice as many absences from training because of these events as the gymnasts did. As a whole, these data do not indicate a high risk of infection in the gymnasts.

In conclusion, gymnasts are often believed to be a population at risk for inadequate nutrition or structural and functional alterations because of their tendency to keep a low weight and a lean appearance for better athletic performance and because they start intensive training at a very young age. In this study, body-composition analysis showed a lower percentage of body fat in the gymnasts, even though BIVA indicated that FFM and body-cell mass fell within the range of the general population for age and sex, thus suggesting good form and health. Moreover, there was no difference in infection incidence or in absences from school between gymnasts and controls.

Gymnasts’ dietary habits were similar to those of age-matched controls, with some positive aspects in the former, namely a better distribution of the daily energy intake, higher fiber levels, and lower cholesterol content. This could be interpreted as a positive influence of athletic activity. We also found some negative aspects affecting both groups, such as an insufficient mineral intake (especially calcium and iron), a low energy intake at breakfast in favor of snacks, and a low level of fluid intake. Thus, more attention must be placed on adolescents’ eating behaviors,
and on gymnasts’ dietary habits in particular, to avoid excessive deficiencies and to guarantee the demands of both growth and sport.

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