Body composition and energy balance assessment of élite female athletes in the USA and Greece

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Keywords

Energy, Women

Abstract

The purpose of this study was to determine body composition, energy balance and tendencies towards eating disorders of female competitive athletes in two countries, USA and Greece. Data were collected using similar methodology in both countries during the non-competitive (training) and the competitive seasons. Forty-two athletes and 11 controls in the USA and 35 athletes and ten controls in Greece participated in the study. Comparison of the results between the countries showed that US athletes weighed more than Greek athletes but there was no significant difference in the percentage of body fat between the two groups. No significant differences were found in the energy intakes between athletes in either country. Athletes appeared to be in negative energy balance (–380 to –580 kcals daily) in both seasons, in both countries.

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Introduction

Health as well as physical performance in athletes is dependent on many factors including nutritional status. Owing to their higher levels of activity, athletes have special energy and nutrient needs in comparison to the general population (Brotherhood, 1984).

The number of women participating in sports has increased significantly over the last decades. The increase has led to a greater interest in the specific nutritional needs of female athletes. A number of investigators have reported that female athletes often show poor dietary behaviours that have been related to disorders such as anorexia, amenorrhea, and osteoporosis. Amennorhea, for example, has been reported to affect up to 50 per cent of competitive runners, 44 per cent of ballet dancers, 25 per cent of non-competitive runners and 12 per cent of swimmers and cyclists (Calabrese *et al.*, 1983; Sayborn *et al.*, 1982). The prevalence of bulimia and anorexia nervosa also has been reported to be very high among athletes (Sundgot-Borgen, 1994).

Studies on female athletes have revealed low reported energy intakes in comparison to high levels of energy expenditure (Brotherhood, 1984; Calabrese *et al.*, 1983 ; Clark, 1991; Nelson *et al.*, 1986). These low reported energy intakes have been associated with marginal intakes of several important nutrients such as calcium, iron and several vitamins. Researchers have questioned how athletes can remain weight stable and perform successfully with an apparent low energy and nutrient intake. Different explanations have been given for this problem (Edwards *et al.*, 1991; Keith and O'Keeffe, 1989).

Most studies concerned with athletes have been of short duration and conducted in small groups in specific sports. The present study aimed to examine anthropometric characteristics and to assess dietary intakes and energy balance over a longer period of time by covering both the competitive and the non-competitive athletic seasons. The study was carried out in two countries, USA and Greece, using similar methodology to compare body composition and energy balance. In each country, athletes from four different types of sports as well as a non-athletic control group participated in the study.

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Methodology

Subjects

In the USA, women athletes were recruited on a volunteer basis from four athletic teams (basketball, gymnastics, swimming and tracking) at the University of Rhode Island. The control group, matched with the athletic group, were women who did not exercise regularly and who were recruited from advertisements in classrooms at the same university.

Initially, 53 athletes agreed to participate; 11 were dropped from the study because of injury or failure to complete dietary and activity records. The final sample consisted of 42 athletes (six basketball players, 16 gymnasts, 11 swimmers and eight track athletes) ages 18-22 and 11 controls, ages 18-23.

The women athletes in Greece were also recruited on a volunteer basis from four athletic teams in Thessaloniki. The control group matched with the athletic group was composed of students of the Technological Educational Institution of Thessaloniki who did not exercise regularly. Initially 46 athletes and 12 controls participated in the study, but during the competitive season 11 athletes and two controls failed to complete the records and were eliminated from the study. The final sample consisted of 35 athletes (eight volleyball players, 11 middle distance runners, nine swimmers and seven ballet dancers) ages 18-26, and ten controls aged 18-25. In both countries, data were collected twice over the non-competitive (September-December) and the competitive (January-March) seasons of the athletic teams. In the non-competitive season athletes were practising but not competing. During the competitive period athletes were both practising and competing in games or meets.

This project has been approved by human subjects review committees in both countries. Even though due to local restrictions, the athletic groups were not all exactly the same in the two countries, the sports chosen belong to similar categories (basketball-volleyball, track-distance running, gymnastics-ballet dancing). It should be mentioned, however, that the comparisons made between the two countries refer to all athletes as a unit. The comparison between individual sports has been made only within the same country.

Anthropometric data – body composition

Height in the USA was measured in inches using a non-stretchable tape measure attached to a wall. Values were then converted to metres. In Greece, height was directly measured to the nearest centimetre with the same method. Weight in the USA was measured in the afternoon, with participants wearing light clothing. Weight was recorded in pounds and converted into kgs. In Greece, weight was recorded to the nearest 0.1kg. Weight in both countries was measured twice during the competitive and the non-competitive seasons. BMI was calculated for all subjects (wt(kgr)/ht(m^2). Percent body fat was determined in both seasons from skinfold and bioelectrical impedance. In Greece, body fat also was determined by hydrostatic weighing. Four skinfolds were taken in both countries; triceps, abdomen, suprailliac and thigh, using Lange skinfold calipers (Ponderal fat meter; Nederland b.v.). Body density was calculated using the formula of Jackson *et al.* (1980). Body density was converted to percentage body fat using the Siri equation (McCardle *et al.*, 1994). Fat free mass was computed by subtracting the value for fat mass, determined using the skinfold method, from body weight.

Bioelectrical independence (BIA) measures of body fat were taken using the RJL Systems (BIA 106, RJL Systems Inc., Clinton Tap, NI) in the USA and the Maltron instrument (BF 905) in Greece. All subjects were instructed to avoid caffeine and drink water to ensure adequate hydration. In Greece, body composition also was determined using hydrostatic weighing. After several practice trials, ten trials were performed and the weight used was the highest value that was reproduced twice. Percentage body fat was calculated from body density using the Siri equation (McCardle *et al.*, 1994).

Dietary intake

In both countries, data for dietary intake were obtained through consecutive, three-day dietary records (two weekdays and one weekend day) collected three times during each season. Thus, records were obtained for 18 days for each athlete during the study; nine for the non-competitive and nine for the competitive seasons. Subjects were given detailed instructions of how to record intake. Dietary data were analyzed using the Nutritionist IV computer program (N^2 Computing, San Bruno, Ca.). Standardized procedures for

collecting data were used, same in both countries.

Energy balance

Energy intake was calculated from dietary records. Data for energy expenditure was collected through the use of activity records. Activity records were collected for the same days for which dietary records were kept. Subjects were provided with forms for recording information and were given written and oral instructions on how to record activities. All activities were converted to their caloric equivalent using the tables proposed by Ainsworth *et al.* (Ainsworth *et al.*, 1993).

Resting metabolic rate (RMR) for all athletes and controls in both countries was calculated using the equation of Owen *et al.* (Owen *et al.*, 1986). Twenty-four hour energy expenditure was calculated by totaling RMR plus energy costs for all activities. Energy balance was determined by subtracting calculated energy expenditure from reported energy intake.

Statistical analysis

The statistical analysis was performed using the SPSS computer program. For all data means and standard errors of the mean were computed and unpaired and paired *t*-tests as well as analysis of variance were used to determine statistical differences between the samples.

Results

Table I shows the descriptive and anthropometric characteristics of athletes and controls in the two countries. Athletes from both countries were of a similar height. However, USA athletes weighed more, leading to a higher BMI. Percentage body fat assessed from skinfold measurements was similar in both groups whereas, fat free mass was higher for USA athletes. Within USA athletes, gymnasts were the shortest and tended to weigh less than the other teams. In Greece, ballet dancers and middle distance runners were shorter and had lower weights compared with volleyball players and swimmers.

After comparing the non-competitive to the competitive season, the data showed that athletes in the USA decreased their weight (–1.3kg), BMI and percent body fat (–1.9 per cent). Greek athletes also decreased their weight (–0.8kg), BMI and percent body fat (–0.8 per cent) in the competitive season.

In the USA, there were no significant differences found for height, weight and BMI between athletes and controls. Percent body fat was lower for athletes only in the competitive season. In Greece, height and weight were significantly higher for athletes compared with controls. Percent body fat was significantly lower for athletes in both seasons.

Table II shows the results for reported energy intake, energy expenditure and energy balance for athletes and controls in both seasons in the two countries. Greek athletes had a lower total energy intake in the non-competitive season compared with the USA athletes, but this difference disappeared when energy intake was expressed as kcal/kg body weight. However, during the competitive season, USA athletes decreased their energy intake so that no significant difference was found in total energy intakes of Greek versus USA athletes during this season. In the USA, intake of controls tended to be lower than athletes in both seasons, but the differences were not statistically different. In Greece, no statistically significant differences were found for the reported energy intake between athletes versus controls in the non-competitive season. In the competitive season, energy intake of the athletes was slightly higher but not statistically different to that of the control group.

When the energy expenditure (EE) of athletes of the two countries was calculated, it was shown that although total EE was higher for USA athletes in the non-competitive season, there was no difference when energy expenditure was expressed as kcal/kg body weight. Furthermore, USA athletes had a lower energy expenditure per kg body weight than Greek athletes in the competitive season. USA athletes decreased their energy expenditure in the competitive season whereas, an increase was found for the Greek athletes when energy expenditure was expressed as kcal/kg body weight.

In both countries, energy expenditure of controls was significantly lower than that of the athletes.

When the different types of sports were studied in the USA, no difference was found between the type of sports in the reported energy intake, but gymnasts had the lowest energy expenditure compared with other sports. In Greece, ballet dancers reported the

Table I Anthropometric measures for athletes and control subjects in the USA and Greece in the non-competitive (NC) and the competitive seasons (C)

	USA				Greece			
	Athletes (n = 42)		Control (n = 11)		Athletes (n = 34)		Control (n = 10)	
Variable (n = 10)	**NC**	**C**	**NC**	**C**	**NC**	**C**	**NC**	**C**
Age (yr)	19.6±1[a]		20.6±1.4[b]		21.4±2.6		22.0±2.2	
Height (m)	1.65±0.8		1.64±0.6[a]		1.68±0.8		1.58±5.1[b]	
Weight (kg)	61.8±8.6	60.5±8.4[b]	61.3±6.7[a]	60.9±7.0[a]	58.6±7.5	57.8±7.4[c]	52.6±3.0[b]	51.8±3.2[b]
BMI (kg/m^2)	22.7±2.1[a]	22.2±2.1[a,c]	22.7±2.0[a]	22.5±2.0[a]	20.7±1.6	20.4±1.6[c]	20.8±1.0	20.3±1.1
Fat free mass (kg)	50.8±6.2	50.9±5.9[a]	49.5±4.7[a]	48.7±4.3[a]	48.0±5.3	47.9±5.3	40.3±2.2[b,d]	39.3±2.7[b]
Percentage body fat								
Skinfold	17.6±3.6	15.7±3.3[c]	19.1±2.3[a]	19.7±3.4[a,b]	17.7±3.8	16.9±4.0[c]	23.2±3.3[b]	24.1±4.1[b]
BIA	24.3±4.4[b,d]	19.9±4.9[a,c,d]	23.8±5.7[d]	22.4±5.9	16.4±5.1[d]	14.7±4.5[c,d]	21.1±3.4[b]	21.0±3.5[b,d]
Hydrostatic					17.5±4.4	16.5±3.7[c]	23.2±3.7[b]	22.3±3.4[b]

Notes:
[a] Indicates significant differences between athletes and control within each country ($p < 0.05$)
[b] Indicates significant differences between seasons within each country ($p < 0.05$)
[c] Indicates significant differences between countries ($p < 0.05$)
[d] Indicates significant differences between methods used to assess body composition ($p < 0.05$)

Table II Energy intake (EI), energy expenditure (EE), and energy balance of athletes and controls in USA and Greece in the non-competitive seasons (C) (mean ± standard error of the mean)

	USA		Greece	
Variable	**Athletes (n = 42)**	**Controls (n = 11)**	**Athletes (n = 35)**	**Controls (n = 10)**
EI (kcal/day)				
NC	1964±439[b,c]	1782±280	1734±500	1712±526
C	1857±385[a]	1768±341	1876±654[c]	1558±508
EE (kcal/day)				
NC	2477±372[b,c]	2183±186[b]	2315±311[c]	1693±50
C	2359±328[a,c]	2144±212[b]	2358±247[c]	1633±32[a]
Energy balance (EI-EE)				
NC	–514±529	–400±347	–580±573[c]	19±539
C	–502±441	–376±453	–482±685[c]	–75±503

Notes:
[a] Indicates significant differences between seasons within a country ($p < 0.05$)
[b] Indicates significant differences between countries ($p < 0.05$)
[c] Indicates significant differences between athletes and controls within each country ($p < 0.05$)

lowest energy intakes in the competitive season compared with the other teams. No significant differences were found in the energy expenditure between the different types of sports.

Athletes in both countries in both seasons appeared to be in negative energy balance.

Discussion

In the present study, athropometric measurements, energy balance and eating disturbances assessments were carried out in two countries; the USA and Greece. Athletes from four different types of sports in each country participated as well as a non-athletic control group. The study was conducted in both the non-competitive and the competitive athletic season.

The mean non-competitive and competitive measures of BMI in both countries in athletes and controls fell within the range of 20-25, considered to be desirable for adults (Lee Nieman, 1993). Athletes as well as controls in Greece had lower mean BMI values compared with the USA subjects. This probably reflects overall differences between the female populations of the two countries. The mean percent body fat obtained from skinfold measurements for both athletes and

controls in both countries fell between the range of 16-24 per cent, considered to be optimal for women (Lee and Nieman, 1993). However, percentage body fat varied greatly between athletes. In Greece, middle distance runners had the lowest percentage body fat (14.3±2.7) whereas volleyball players had the highest (19.4±3.4). In the USA, the lowest percentage body fat was found for gymnasts (15.2±2.5) and the highest for swimmers (19.3±2.2).

The mean energy intake of the USA and Greek athletes fell within the range of 1,600-2,100 kcals reported as energy intakes of female athletes by other investigators (Barr, 1987; Duester *et al.*, 1986; Edwards *et al.*, 1991). It should be noted though, that there was a great variation in energy intakes among athletes. Reported energy intakes for individual athletes ranged from 1,293-2,373 kcal (NC) and 1,528-2,760 kcal (C) for USA athletes, and from 1,045-2,657 kcal (NC) and 1,131-3,451 (C) for Greek athletes. No significant difference was found between energy intakes of athletes and the controls in either country. This also has been reported by other researchers (Mulligan amd Butterfield, 1990; Myerson *et al.*, 1991).

Athletes in both countries failed to meet the recommended 45-50 kcal/kg body weight for women who train >90 minutes. This was also found to be true when the results for individual teams were examined.

Energy expenditure was found to be significantly higher, in both countries, for athletes compared with controls in both seasons. This also has been reported by other investigators and it is expected since athletes are more active than sedentary individuals. A difference was found between the energy expenditure of the Greek athletes versus USA athletes. USA athletes decreased their energy expenditure during the competition season showing an overall decrease in activity level whereas Greek athletes increased the kcals/kg body weight used between seasons. This may reflect differences in the exercise practices between the two countries. Furthermore, differences have been found within the same country between types of sports. In the USA, the basketball team had the highest decrease of EE in the competitive season indicating lighter practices. In Greece, volleyball players had the largest increase in energy expenditure between seasons.

One finding in the present study that also is consistent with what has been found in other studies (Edwards *et al.*, 1991; Mulligan and Butterfield, 1990; Myerson *et al.*, 1991) is the discrepancy between reported energy intake and calculated energy expenditure. This discrepancy has been found to be higher for athletes in Greece. Athletes tended to lose weight, but the reported weight loss was not great enough to explain the discrepancy in energy balance. Another explanation can be found in the errors inherent in the methodology for assessing food intake and for estimating energy expenditure. One of the main errors associated with diet records is under reporting of food intake (Mertz, 1992; Schoeller, 1983). Under reporting can occur because subjects fail to record portions of food correctly, omit foods eaten or restrict their food intake during the period of the study. Edwards *et al.* (1991) believe that under reporting may be unconscious and may be related to perceived body image.

Cultural differences between the countries or differences in dietary habits or patterns did not seem to affect either energy intakes or energy expenditure of athletes. Athletes were in negative energy balance in both countries.

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