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Body composition and nutritional habits in professional ballet dancers

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Object of this study was to study fat mass (FM), fat-free mass (FFM) and nutritional habits of professional ballet dancers. Our secondary aim was to evaluate daily energy intake and to compare nutritional habits with level of daily recommended consumption (LARN) or recommended dietary allowance (RDA). Twelve ballet dancers (seven males and five females), aged between 23-42 years were studied. All the subjects trained at least 5 h per day (mean ± SD: 8 ± 3). We used four different techniques to assess body composition: skinfold thickness measurements (TH), bio-electrical impedance analysis (BIA), air displacement plethysmography (BOD-POD) and dual energy X-ray absorptiometry (DXA). The latter was considered the criterion method. FM using DXA was 6.2 ± 2.0 kg and FFM 56.3 ± 12.4 kg in the total population. FM was 5.2 ± 1.1 kg and 6.9 ± 2.3 kg in females and males using DXA, respectively. FFM in females was 44.6 ± 4.8 kg and 64.7 ± 8.2 kg in males. Correlation between FM derived by skinfolds vs FM measured by DXA was significantly higher (r = 0.90) than between FM estimated by BIA (r = 0.54) and by BOD-POD (r = 0.48). Positive correlations were found between DXA FFM measurements and FFM anthropometry (r = 0.99), between DXA FFM and FFM estimated by BIA (r = 0.98) and between FFM measured by BOD-POD (r = 0.99). Total energy intake in male subjects was less than LARN or RDA (2464 ± 256 vs 3100 ± 379 kcal/day). On the other hand, total energy intake in female subjects was slightly higher than LARN or RDA (2439 ± 391 vs 2120 ± 130 kcal/day). This was probably due to a higher energy consumption from lipids in female subjects (32 ± 7% in males vs 36 ± 7% in females). Our results suggest that FM estimated by anthropometry is to be preferred to BIA in this specific population, possibly because the main part of FM in this specific population is only subcutaneous.

Key words: ballet, body composition, fat mass, fat- free mass, dietary intake, calcium.

Introduction

Ballet is an artistic dance performed as a theatrical entertainment. It is a combination of equilibrium and harmony emphasizing the principles of balance and grace. Ballet dancing is also a demanding occupation that requires excellent athletic performance and the maintenance of a thin body shape. As a result ballet dancers tend to restrict caloric intake in order to maintain a low body weight [1, 2]. The study of body composition in ballet dancers is a peculiar task, because the different factors involved in this discipline may have both positive (ie weight-bearing exercise) and/or negative (ie chronic strenuous exercise, low dietary intake, low body mass, hormonal imbalance) effects on body composition. There is a fundamental need for ballet dancers to find a balance between sufficient energy intake for high-level performance and the maintenance of good health [2,3]. Studies in ballet dancers show conflicting results for ballerinas for whom thinness and appearance are particularly important and among whom laxative use, self-induced vomiting, and use of diuretics in order to lose weight and reduce body fat is common [4]. Many ballet dancers engage in dieting activities to achieve a thin physique with consequences such as hypothalamic dysfunction [5], amenorrhea, late menarche [6,7] and low total body mineral density [2].

Controversial results are reported in the literature regarding accurate measurements of energy intake in special populations, such as classical ballet dancers. Weighed intake methods have been used to assess energy and nutrient intake [8,9]. These studies suggested that in order to accomplish the thinness desired by managers many ballet dancers resort to chronic energy intake restriction and consequently do not meet the requirements for energy and nutrients intake such as calcium. These findings were based on the assumption that energy intake derived from dietary records is accurate. On the other hand [10] low energy intake in ballet dancers may be related to under-reporting. However, the superior ability of the

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7-day food diary to report food intake has been confirmed [11], which is also an indirect method of assessing energy intake.

Only a few people perform classic dance and they represent an elite similar to those engaging in skating [12] or synchronized swimming [13] at high performance levels. For this reason, studies of this population have observed small numbers of subjects.

Body composition in athletes is estimated using different techniques [5]. Data on body composition of ballet dancers have been obtained by skinfolds and underwater weighing [14]. The classical two-component model, however, is limited by the consumption related to the constant composition of fat-free mass (FFM) [15]. Due to change in bone mineral density (BMD) and hydration of the FFM, skinfolds and underwater weighing may not give valid results. The reference methods for the assessment of both fat mass (FM) and FFM may be computed tomography (CT) and magnetic resonance (MRI) [16]. Dual-energy X-ray absorptiometry (DXA), another technique that has been proposed for the assessment of body composition, compares very well with CT and MRI [17,18,40]. The three-compartment DXA model separates body mass into FM, lean tissue mass (LTM) and bone mineral content (BMC), where the sum of LTM and BMC represents FFM [19]. CT, MRI and DXA cannot be used routinely, mainly because of logistical problems, cost and radiation exposure [20]. In our study we investigated body composition in ballet dancers using four different techniques: skinfold thickness measurements (TH), bio-electrical impedance analysis (BIA), air displacement plethysmography (BOD-POD), and DXA. DXA was used as the reference method [21]. Comparative studies of BIA vs DXA have shown that four-polar BIA gives accurate estimates of FFM in adult subjects [17,18,22,23] and use of frequencies >50kHz may improve the estimate of body composition from BIA due to better penetration of the electrical current into intracellular water [24]. BOD-POD is a reliable and valid technique that can quickly and safely evaluate body composition in a wide range of subjects [25].

The aim of our study was to investigate body composition in professional ballet dancers using TH, BIA and BOD-POD with DXA as the reference method. Our secondary aim was to evaluate energy intake, using 7-day weighed diary records, and the relationship between bone and calcium intake.

Subjects and methods

Subjects

Twelve professional ballet dancers (seven males and five females) aged 23 to 42 years and recruited from the Ater-Balletto Fondazione Nazionale della Danza compagnia di Reggio Emilia, Italy took part in the study. All females had regular menstruation in the twelve months prior to the study and none used contraceptive pills. Measurements were carried out during the first two weeks after menstruation. All the subjects trained at least 5 h/day during the period of the study (mean 8 ± 3 SD). All dancers filled out medical and nutritional forms, none of the dancers was considered to have eating disorders (anorexia and/or bulimia) and none reported smoking or drinking habits.

After being informed about the study, all subjects signed a written informed consent form. The study was approved by the Medical Ethical Committee of the University of Modena and Reggio Emilia, Italy.

Methods

Anthropometry. All anthropometric measurements were performed by the same operator according to the Anthropometric Standardization Reference Manual [15]. Weight (Wt) was measured to the nearest 100 g and height (Ht) to the nearest 0.1 cm using an electronic balance with an incorporated stadiometer (Tanita, Tokyo, Japan). Body Mass Index (BMI) was calculated as Wt/Ht^2 (kg/m^2).

Skinfolds and circumferences were measured by a caliper and an anthropometric tape, respectively (Holtain, Crymich, UK). Skinfold thickness (biceps, triceps, subscapular, supra-iliac, calf and medium thigh) were measured to the nearest millimeter using calipers on the right side of the body [15]. Circumferences (arm, waist, hip, calf and medium thigh) were measured to the nearest millimeter using a plastic tape measure. All skinfolds and circumferences measurements were done three times and the three values were averaged. Arm muscle area (AMA) and arm fat area (AFA) were calculated from arm circumference and triceps skinfold as described by Heymsfield et al. [26].

Bioimpedance analysis. Bioimpedance was measured using an eight-polar tactile-electrode impedance-meter (In Body 3.0, Biospace, Seoul, Korea). Body resistance (R) of arms, trunk and legs was measured in fasting subjects at frequencies of 5, 50, 250 and 500 kHz with eight-polar tactile-electrodes: two were in contact with the palm and thumb of each hand and two with the anterior and posterior part of the sole of each foot (Fig. 1). The subjects stood with their soles in contact with the foot electrodes and grasped the hand electrodes. An alternating current of 250 μA of intensity (I) was applied between E1 and E5. The recorded voltage difference (V) between E2 and E4 was divided by I to obtain the resistance of right arm (R_{RA}). The same operation was performed with V recorded between E4 and E8 to obtain trunk resistance (R_T) and with V recorded between E6 and E8 to obtain the resistance of right leg (R_{RL}). The alternating current was then applied between E3 and E7 and the value of V, measured between E2 and E4, was used to calculate the resistance of left arm (R_{LA}). The value of V measured between E6 and E8 was used to calculate the resistance of left leg (R_{LL}). No precautions were taken to standardize the subject's posture before BIA, as suggested by the manufacturer. Segmental RI was

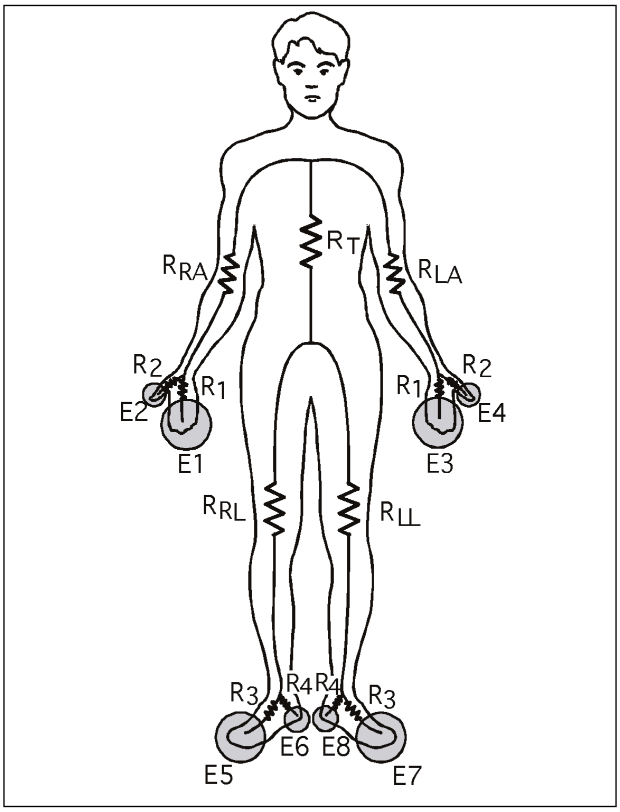

Figure 1. Measurement pathways of In Body 3.0 (graph reproduced by courtesy of Biospace). The subject stands with her or his soles in contact with the foot electrodes and grabs the hand electrodes. Abbreviations: R_{RA} = resistance of right arm; R_T = resistance of trunk; R_{LA} = resistance of left arm; R_{RL} = resistance of right leg; R_{LL} = resistance of left leg.

calculated as Ht $(cm)^2/R_x$ (Ω), where R_x was the resistance of arm or leg at frequency x. Whole-body resistance (R_{sumx}) was calculated as the sum of segmental R_x (right arm + left arm + trunk + right leg + left leg). The whole-body resistance index (RI_{sumx}) was calculated as Ht $(cm)^2/R_{sumx}$ (Ω). The between-day precision determined by three daily measurements of two subjects for five consecutive days was ≤2.7% (≤5 Ω) and the within-day precision was ≤2.0 (≤3 Ω).

Measurements were performed in the morning at room temperature (21°) after at least 12 hours of rest, following an overnight fast.

Air displacement plethysmography. Body density was performed using air displacement plethysmography (BOD-POD, Life Measurement, Inc, Concord, CA, USA). Subjects were measured in swimsuit with swim cap to minimize the effect of the hair on body volume assessment and with all jewelry removed [27,39]. Body mass was first measured to the nearest 0.02 kg on a calibrated electronic scale. Each subject was then asked to sit in the air displacement plethysmograph for body volume measurement. Subjects were instructed to sit quietly with an erect posture and normal respiration, with their hands folded in their laps and their feet placed on the floor of the device. A minimum of two 50-s tests were conducted to ensure reliability of measures.

The body volume measurement was repeated if the two measures were not within 150 ml of each other [27]. After these initial measurements, subjects were connected to a breathing circuit internal to the system for the assessment of thoracic gas volume. The subjects were instructed to apply a nose clip and to continue normal breathing for < 2–3 full breaths to allow the system to record a real-time breathing record on the computer screen. The investigator observed this breathing pattern and informed the subjects just before airway occlusion. Subjects then alternately contracted and relaxed the diaphragm while airway and chamber pressures were recorded simultaneously. Once these measurements were completed (after <3–5 min), body density (Db) was calculated using the following equation:

$$Db = mass/Vb$$

where Vb is body volume determined by BOD-POD. Percentage body fat (%BF) by BOD-POD was derived using Siri's formula [28]:

$$\%BF = [(4.95/Db - 4.50) * 100]$$

Dual energy X-ray absorptiometry. DXA scans were performed by the same operator using a Lunar DPX-L densitometer with adult software (version 3.6, Lunar Corporation, Madison, WI, USA). The DXA method is based on 3-compartment model that divides the body into total body mineral, mineral free lean and fat tissue masses. The principle is that a double photon beam generated by an x-ray source can differentiate between bone mineral content and soft tissue. After evaluation of bone mass the technique can determine the fat and fat-free component of the soft tissue [19]. The reproducibility of the measurement is 1.2 % for FM [29] and 0.7 % for FFM [30] .

Energy intake was obtained using the 7-day dietary record. Each subject was asked to record the weight of all food and beverages consumed and to record brand names, methods of food preparation and ingredients of recipes in a diary. Subjects were additionally asked to record the amount of any leftover food eaten either at home or out. All food records were reviewed with the subject upon collection and analysed using commercial available software and converted in nutrients (Dietosystem, Milan, Italy). Where corresponding food items could not be found in the software the item's energy content was derived from published food tables. Instructions regarding the completion of the diet records were given in detail to the subjects by an expert dietitian. Dietary intakes were compared with level of daily recommended consumption (LARN) [31] or recommended dietary allowances (RDA) [32] recommendations for a healthy diet.

Table 1. Physical characteristics of the study population.

Subject	Age	Gender	Weight (kg)	Height (cm)	BMI	FM_{BodPod} (kg)	FFM_{BodPod} (kg)	FM_{DXA} (kg)	FFM_{DXA} (kg)	FM_{BIA} (kg)	FFM_{BIA} (kg)	FM_{TH} (kg)	FFM_{TH} (kg)
1	25	F	50	1.63	18.8			6.1	43.9	7.5	42.5	7.1	42.9
2	24	F	47	1.59	18.5	5.6	41.4	4.8	42.2	6.5	40.5	6.7	40.3
3	28	F	55	1.63	20.7	5.8	49.2	6.6	48.4	8.9	46.1	7.7	47.3
4	32	F	54	1.75	17.6	3.4	50.6	3.8	50.2	5.1	48.9	5.2	48.8
5	27	F	43	1.54	18.1	5	38	4.8	38.2	6	37	6.0	39.9
Mean±SD	27±3		50±5	1.63±8	19±1	4.9±1.1	44.8±6.1	5.2±1.1	44.6±4.8	6.8±1.5	43±4.7	6.5±0.9	43.9±4.0
6	28	M	70	1.83	20.7	3.2	66.8	3.4	66.6	5.4	64.6	4.3	65.7
7	23	M	85	1.80	26	6	79	5.1	79.9	14.7	70.3	6.6	78.4
8	32	M	67.5	1.75	22	7.1	60.4	8.1	59.4	10	57.5	7.9	59.6
9	25	M	60.5	1.70	20.8	4.4	56.1	5.4	55.1	8.7	51.8	4.9	55.6
10	31	M	78	1.78	24.6	1.5	76.5	8.3	69.7	10.5	67.5	7.4	70.6
11	42	M	69	1.75	22.4	2.8	66.2	7.5	61.5	9	60	7.1	61.9
12	42	M	71	1.75	23	11	60	10.3	60.7	10.7	60.3	11.2	59.8
Mean±SD	32±8		72±8	1.77±4	23±2	5.1±3.2	66.4±8.6	6.9±2.3	64.7±8.2	9.9±2.8	61.8±6.27	7.1±2.2	64.5±7.8

FM_{BodPod}=fat mass BOD-POD; $FFM_{Bod-Pod}$=fat-free mass BOD-POD; FM_{DXA}=fat mass DXA; FFM_{DXA}=fat-free mass DXA; FM_{BIA}=fat mass BIA; FFM_{BIA}=fat-free mass BIA; FM_{TH}=fat mass TH; FFM_{TH}=fat-free mass TH.

Table 2. Daily energy and nutrient intake of ballet dancers

Subject	Sex	Daily intake(kal/day)	TEE	Carb (%)	Simp.Carb(%)	Comp.Carb.(%)	Prot(%)	Fat(%)	Fibre (g)	Calcium
1	F	1957	2100	53.6	38	62	16.6	26.8	25.6	423.6
2	F	2989	2000	49	59.4	40.6	13	38	34	1116.9
3	F	2628	2300	51.3	60	40	13.2	35.5	14.9	693.9
4	F	2251	2200	41.1	55	45	13.3	45.6	10.2	945.5
5	F	2368	2000	53.9	34	66	11.8	34.4	13.7	748.2
Mean±SD		2439±391	2120±130	50±5	49±12	51±12	14±2	36±7	20±10	786±263
6	M	2668	2900	37	57	43	20	40	14.1	115.9
7	M	2114	3200	64.6	48	52	12.9	22.5	12.8	651.4
8	M	2676	2800	64.2	38	62	12.1	23.7	12.9	736.6
9	M	2128	3900	44.3	27	73	19	36.7	7.3	642.5
10	M	2420	3100	41	28	72	13	39	5.9	597.1
11	M	3023	2900	48.3	19	81	14.5	37	15.6	1238.2
12	M	2156	2900	58.3	31	69	11.6	30.1	16.1	811.9
Mean±SD		2464±256	3100±379	53±9	34±11	66±11	14±2	32±7	12±4	838±265

TEE=total energy expenditure by LARN/RDA; Carb= total carbohydrates; Simp. Carb=simple carbohydrates; Comp. Carb=complex carbohydrates; Prot=protein; Fat= fat.

Statistical analysis

Data were analyzed using a PC version of Stata. Linear Pearson (p) correlation was used to evaluate the relationship between the different methods of fat mass assessment. The Bland – Altman procedure [33] was also used to examine the pair-wise comparison between percentage of FM and FFM measured by DXA and other body composition methods (BIA, BOD-POD and TH). Statistical significance was set at $P<0.05$

Results

Baseline subject's characteristics as well as body composition data are reported in Table 1. Mean energy and nutrient intake are summarized in Table 2. No significant difference was found between measurements of FM and FFM using the different techniques. The correlation coefficients between FM and FFM measured with the different techniques are summarized in Table 3. Positive correlations were found between DXA FFM measurements and TH (r = 0.99), between DXA FFM measurements and BIA (r = 0.98) and between DXA FFM measurements and BOD-POD (r = 0.99) (Table 3).

The correlation of %FM measured by TH (r = 0.90) and %FM performed by DXA was significantly higher than the correlation between FM done by BIA (r = 0.54) and by BOD-POD (r = 0.48) (Table 3). Bland-Altman analysis did not reveal any systematic difference between FM and FFM measured with the four different techniques.

The mean absolute food intake is shown in Table 2. No significant differences were found in dietary

Table 3. Cross-sectional correlation of fat mass and fat-free mass assessment estimates by DXA and the other three techniques (BIA, BOD-POD and TH).

	DXA/BIA	DXA/BOD-POD	DXA/ TH
FFM	0.98	0.99	0.99
FM	0.54	0.48	0.90

intake between the different measurements taken at different days (data not shown). All subjects ingested food during the three major eating occasions (ie breakfast, lunch and dinner). There was little variation in intakes of afternoon and evening snacks (data not shown). Total energy intake in male subjects was less than LARN or RDA (2464r±r256 vs 3100 ± 379 kcal/day). On the other hand, total energy intake in female subjects was slightly higher than LARN or RDA (2439 ± 391 vs 2120 ± 130 kcal/day) possibly because women had more energy intake from lipids (32 ± 7% in males vs 36 ± 7% in females).

No significant difference was found in carbohydrate and fat intake during the three major eating occasions in both male and female groups, but fat intake as percentage of energy was higher in females' diaries than in males' diaries. No relationship was found between macronutrient and body composition, in particular no correlation existed between bone mineral content and calcium intake.

Discussion

This study used four different methods to evaluate FM and FFM in a group of ballet dancers. Although the DXA method has gained credibility and acceptance in the past few years [2], it has not yet been established as a 'gold standard. However, it can be considered a reference method due to its precision and accuracy [34] .Therefore in this study we compared estimates of FM and FFM by TH, BIA and BOD-POD to estimates of FM and FFM by DXA. We also estimated the energy intake of the subjects studied and compared it to the LARN or RDA for subjects/athletes of same age and gender.

We found significant positive correlations between all four methods of FFM and FM assessment and no meaningful difference between DXA and the other three methods. Assuming that DXA was previously validated to measure body composition (FM and FFM) among ballet dancers [2], we suggest that TH, BIA and BOD-POD measurements of FM and FFM can serve as good alternative methods. TH measurement may be better than BOD-POD and BIA measurements for the assessment of FM. This may suggest that skinfold estimates of FM should be preferred to BIA in this specific population. The moderately high correlation of FM assessment by TH and DXA may be related to the low FM of this population since the accuracy of TH measurement decreases as FM increases [35]. Nevertheless it is important to highlight that while TH measurement can be used successfully in cross-sectional studies to evaluate FM, it is not reliable to detect changes [36,37].

We also evaluated the energy intake of this population and found that the total energy intake of male subjects was less than LARN or RDA . On the other hand, the total energy intake of female subjects was slightly higher than LARN or RDA , possibly because females had more energy intake from lipids. In females, lipids intake was higher than LARN or RDA. No correlation was found between bone mineral content and calcium intake. This finding is similar to that of Restrepo et al. [38] who evaluated 59 professional young high-performance athletes, in three different sports (soccer, roller-skating and swimming) in comparison with 59 normal subjects without high-level physical activity.

Our study demonstrated that a simple, inexpensive method as TH measurement can be successfully used to determine FM and FFM in a homogeneous group of ballet dancers. Although other studies have found same results in professional ballet dancers, the difference is that we included not only female [1,2,6,36], but also male subjects, analysing adults rather than adolescents.

Previous studies carried out on the food habits of ballet dancers analysed calcium intake, but did not report whether the subjects consumed the necessary daily intake for the sport practised, as suggested by LARN or RDA. In contrast we evaluated all the nutrients that ballet dancers consumed in an ordinary week using 7-day diaries.

More studies are needed to confirm our results, particularly because of the low number of subjects involved in this study. Ballet is a very difficult and strenuous discipline; therefore it has been and will be very difficult to find an adequate group of professional ballet dancers. This study confirms that TH measurement is a good and reliable method to estimate FM and FFM in a group of professional ballet dancers.

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