Resting Energy Expenditure in Elite Female Athletes of Different Sports

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Abstract: An optimal balance between energy intake and energy expenditure is essential for athlete performance, therefore, measuring Resting Energy Expenditure (REE) in athletes might help for providing adequate energy needs. This study aimed to evaluate REE measured with indirect calorimetry in elite female athletes practicing ballet dance, volleyball and swimming and if REE varied among the three sport groups after adjustment for fat-free mass (FFM). Elite female athletes aged 18-35 years who train for at least 16/18 hours per week were recruited. Anthropometry, indirect calorimetry and bioimpedance analysis were performed. Ballet dancers had the lowest FFM and FM in both absolute and percentage values ($p<0.05$) compared to other athletes. REE was lower in ballet dancers than in volleyball players (REE:1320±139 kcal/die vs. 1538±124 kcal/die, $p=0.001$) even after adjustment for age. After adjustment for FFM and for both FFM and age, REE was lower in ballet dancers than volleyball players but did not achieve statistical significance. Our study showed that REE in sport is mostly influenced by age and body composition and confirmed that FFM is the major determinant of REE. Further valuations are needed to evaluate if REE could also be influenced by dietary habits as well as by age in which athletes start sport activity.

1 INTRODUCTION

Resting Energy Expenditure (REE) is the amount of energy spent at rest in a fasted state at a thermoneutral condition and it represents more than 60% of total energy expenditure in normal-weight healthy adults (Trexler 2014, Marra 2015). Generally, indirect calorimetry (IC) is the criterion method for measuring REE (McClave 1992), alternatively, REE is estimated by predictive equations and the Harris and Benedict formula (Harris and Benedict 1918), has been the most popular equation used in healthy participants.

Elite athletes have higher energy needs than non-athletic subjects for training and recovery. Since an optimal balance between energy intake and energy expenditure is essential for athlete performance, measuring their REE might help for determining properly their energy requirements. In fact, the under- or overestimation of athlete's energy needs might result in a loss of fat-free mass (FFM), increased fat mass, impaired performance and increased risk of injuries (Loucks 2004; Rodriguez 2009; ten Haaf 2014).

REE is known to be influenced by sex, weight as well as body composition. In fact, the major determinant of REE is FFM. Consequently, the assessment of FFM is of great importance in evaluating REE in athletes.

From a practical point of view, bioelectrical impedance analysis (BIA) is a widely used, non-invasive field method for assessing body composition in athletes. Even more, raw BIA variables such as phase angle (PhA) have been shown to be significantly associated with muscle strength and physical activity (Moon 2013; Mundstock 2019) and to be higher in athletes than general population (Di Vincenzo 2019; Di Vincenzo 2020).

To the best of our knowledge, very little is known regarding REE of female athletes, which can widely vary depending on the sport type. Ballet dance, volleyball and swimming are the most popular sports among females. These are different sport specialties and the type of physical exercise,

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the different trophism, and therefore, body composition of the athletes, varies among these disciplines. To date, REE has not been previously compared between these three different sports.

Therefore, based on this background, the first aim of the study was to evaluate REE measured with indirect calorimetry in elite female athletes practicing ballet dance, volleyball and swimming. Additionally, we aimed to evaluate if REE could vary among the three sport groups after adjustment for FFM.

2 METHODS

Inclusion criteria of the present study were: elite female athletes aged 18-35 years who train for a minimum of 16/18 hours per week. Subjects affected by overt metabolic and/or endocrine diseases and/or regularly taking any medications affecting energy metabolism, were excluded.

All measurements were performed early in the morning after an overnight fast according to standardized conditions, abstention from vigorous physical activity for 24 hours prior to the assessment.

Body weight and stature were measured to the nearest 0.1 kg and 0.5 cm, respectively, using a platform beam scale with a built-in stadiometer (Seca 709; Seca, Hamburg Germany). Body Mass Index (BMI, kg/m²) was calculated as body weight (kg) divided by squared stature (m).

BIA was performed at 50 kHz (Human Im Plus II, DS Medica). Measurements were carried out on the nondominant side of the body, in the post-absorptive state, after voiding and with the subject in the supine position for 20 minutes, with a leg opening of 45° from the median line of the body and the upper limbs, 30° apart from the trunk (Kyle 2004). The BIA variables considered were resistance (R), reactance (Xc), and PhA. FFM was estimated using the Sun equation (Sun et al. 2003). Fat mass (FM) was calculated as the difference between body weight and FFM.

REE was measured by indirect calorimetry (McClave 1992) using a canopy system (V max29, Sensor Medics, Anaheim, U.S.A.).

Measurement conditions for IC were defined following the suggestions made by Compher et al. (Compher 2006) and Fullmer et al. (Fullmer 2015). REE was measured at an ambient temperature of 22-25 °C with the subjects fasting (12-14 hours) and laying down, but awake, on a bed in a quiet environment. REE was assessed during the postmenstrual phase to avoid any potential effects of the menstrual cycle. After a 15-minute adaptation period, oxygen consumption and carbon dioxide production were measured for 45 minutes. Energy expenditure was calculated using the abbreviated Weir's formula, neglecting protein oxidation (Weir 1949). Data were excluded from analysis if the respiratory quotient was outside the expected range (0.71-1.00) and when measured REE was ±3 standard deviations outside the mean REE (Marra 2019).

Statistical Analysis

Statistical analyses were performed using IBM SPSS (version 20). All data are presented as mean±standard deviations (SD), unless otherwise specified. Comparisons between groups were conducted by analysis of variance (ANOVA) and Tukey post hoc test for multiple comparisons was adopted. Significance was defined as $p < 0.05$.

3 RESULTS

Forty elite female athletes (age=27.5±10.9 years; weight=56.6±7.6 kg; stature=166±5 cm; BMI=20.4±2.0 kg/m²) were selected for this study. Anthropometric characteristics of the subjects divided according to sport specialty are summarized in Table 1.

Table 1: Subject's characteristics.

	Ballet dancers (n =10)	**Volleyball Players** (n =15)	**Swimmers** (n =15)
Age (years)	18.6±0.9	22.4±2.7	41.4±6.6*
Weight (kg)	47.7±4.4§	62.7±4.6	59.2±3.0
Stature (cm)	163±5°	169±5	166±3
BMI (kg/m²)	17.9±1.0§	21.8±1.1	21.4±1.0

Data are reported as mean±standard deviation; BMI=body mass index.
$p<0.05$ *=vs all; §=vs all; °=vs volleyball players.

Swimmers were significatively older than other athletes whereas ballet dancers had the lowest weight, stature and, consequently, BMI ($p<0.05$).

Table 2 shows REE, body composition and PhA data of the three groups. Ballet dancers had the lowest FFM and both FM and FM% ($p<0.05$). Otherwise, similar PhA values were observed among the groups.

REE was lower in ballet dancers than in volleyball players (-14.2%, p=0.001) (Table 2) even after adjustment for age (-14.5%, p= 0.001) (Table 3). Otherwise, after adjustment for FFM and for both FFM and age, REE was lower (-7.0% and -7.6%, respectively) in ballet dancers than volleyball players but did not achieve statistical significance as showed in Table 3.

Table 2: Resting energy expenditure, body composition, bioelectrical impedance phase angle.

	Ballet dancers (n =10)	Volleyball Players (n =15)	Swimmers (n =15)
REE (kcal/day)	1320±139°	1538±124	1451±63
RQ	0.81±0.01	0.83±0.60	0.81±0.59
FFM (kg)	40.4±3.8§	47.8±3.6	45.6±2.0
FM (kg)	7.2±1.6§	15.0±1.2	13.6±1.2
FM (%)	15.1±2.8§	23.8±0.9	23.0±1.1
PhA (degrees)	6.95±0.46	6.92±0.38	6.53±0.46

Data are reported as mean±standard deviation; REE=resting energy expenditure; RQ=respiratory quotient; FFM=fat-free mass; FM=fat mass; PhA=phase angle.
p<0.05 °=vs volleyball players; §=vs all.

Table 3: Resting energy expenditure adjusted for FFM and for age.

	Ballet dancers (n =10)	Volleyball Players (n =15)	Swimmers (n =15)
REE adj. age (kcal/day)	1310±64°	1533±48	1465±89
REE adj. FFM (kcal/day)	1385±44	1489±41	1436±35
REE adj. FFM and age (kcal/day)	1362±62	1474±51	1473±81

Data are reported as mean±standard deviation; REE=resting energy expenditure; adj.=adjusted for.
p<0.05 °=vs volleyball players.

4 DISCUSSION

As primary outcome, this study aimed to evaluate REE measured with IC in elite female athletes practicing ballet dance, volleyball and swimming.

Our results showed that measured REE differed between the three groups. Specifically, it was significantly lower in ballet dancers than in volleyball players, probably due to lower weight (-23.9%) and FFM (-15.5%). The difference in REE persisted when it was adjusted for age (-14.5%, p= 0.001) and even for FFM (-7.0%) and for both FFM and age (-7.6%) but in the latter without achieving a statistical significance.

The reduced REE assessed in ballet dancers could be due to a different energy intake, the high performance and because of body image issues (Di Vincenzo 2020). Another explanation is potentially related to the start of the physical preparation in pre-pubertal age because the intense training significantly modifies body composition components (Marra 2019). Additionally, considering that professional ballet dancers have biomechanical changes and functional performance related to intense dance training, they developed a metabolic adaptation at the physical activity, (Yin 2018). However, it should be noted that these results could be affected by the low number of participants among sport groups and by the absence of a control group.

In conclusion our study showed that REE in sport is mostly influenced by age and body composition and confirmed that the major determinant of REE is FFM.

Further valuations are needed to evaluate if REE could be also influenced by dietary habits and the age in which athletes start sport activity.

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