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ORIGINAL ARTICLE

Evaluation of body composition with bioimpedence. A comparison between athletic and non-athletic children

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Abstract
Purpose: Conventional Bioelectrical Impedance Analysis (BIA) or Bioelectrical Impedance Vector Analysis (BIVA) can provide direct evaluations of body composition. The purpose of this study was to evaluate lean and fat mass (FM), and hydration of children involved in daily competitive sports. *Methods:* 190 non-athletic [8.2–10.5 years] and 29 competitive children [8.0–10.5 years] were enrolled. They were evaluated: at baseline (*t0*), 6 months (*t1*) and one year (*t2*). Anthropometric, BIA and BIVA, lean and FM, and hydration evaluations were performed. *Results:* Resistance (R/h) and reactance (Xc/h) were lower at *t*0 in competitive individuals when compared to controls. Xc/h (+3.28) significantly increases in competitive when compared to non-competitive individuals (+0.66, p for difference: 0.011), while phase angle (PA) was lower at *t*0 (5.72 vs. 6.17, $p < .001$) and after 6 months ($p = .001$). Total body water adjusted for height (TBW/h) significantly increased only in non-athletes ($+0.50 \pm 0.13$, $p < .001$) between *t0* and *t1*. At *t1*, extracellular water (ECW) significantly decreased ($p = .026$) in the two groups: $-0.45 \pm 0.19\%$ in non-competitive, $-1.63 \pm 0.49\%$ in competitive subjects, while intracellular water (ICW) increased. At one-year follow-up (*t2*), there were no statistically significant differences in R/h, Xc/h and PA in competitive individuals when compared to baseline and *t1*. Furthermore, we observed at *t2* that hours/week of training, age, male gender and body mass index can influence FFM/h and FM/h in both competitive and non-competitive subjects. In particular, a direct correlation was for hours/week and FFM/h, inverse for hours/week and FM/h. *Conclusions:* Body mass index does not allow evaluating differences in lean body mass and FM between athletes and non-athletes. BIA and BIVA can give more reliable details about body composition differences in competitive adolescents and non-competitive, outlining a progressive decline in ECW and increase in ICW without affecting TBW composition of athletes.

Keywords: *Body composition, BIA, BIVA, paediatric age, sport*

Introduction

Limited evidence exists about the evaluation of body composition and its dynamic changes in children practising sports. Standard methods for this evaluation such as Dual Energy X-Ray Absorptiometry (DEXA) or dilution of deuterium are often used in children for scientific research purposes (Fields, Demerath, Pietrobelli, & Chandler-Laney, 2012). Nevertheless, more compliable instruments should be considered in order to constantly evaluate the children during follow-up visits.

The body mass index (BMI) was used as a surrogate for DEXA in young individuals (Kakinami, Henderson, Chiolero, Cole, & Paradis, 2014). Nevertheless, DEXA measurements are not reproducible in individuals practising sports and did not

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provide a full overview of their nutritional status as they are not a direct indicator of total body fat (Mei et al., 2007). Gender, region of interest and tissue type/mass influence the results from DEXA evaluations: DEXA evaluation of body composition is not completely reliable in athletes and little individuals (Buehring et al., 2014). Although lower radiation doses (~0.5 μSv per 1 whole-body scan) are released during DEXA, the risk for these radiations on body health should considered as a further limitation (Nana, Slater, Hopkins, & Burke, 2012). Beyond technical error due to machine/software or patient's position on the machine, the rapid variations in the composition of human tissues due to exercise alter DEXA measurements (Nana et al., 2012). DEXA performance is not cost-effective, the instrument could not be moved, a specific training is needed and finally it is difficult to compare results from different machines.

Bioelectrical Impedance Analysis (BIA) or BIA Vector (BIVA) can overcome the limitations deriving from BMI/DEXA (Piccoli et al., 1995). BIA and BIVA measure the resistance of a circuit (i.e. the human body) when a mild alternating electric current (50 Hertz, 800 microamps) passes through it. Therefore, resistance (R) and reactance (Xc) are measured (Piccoli et al., 1995). The former is influenced by the intra- and extracellular fluid properties to counteract the passage of electric current: thus, its value is inversely related to tissue hydration and, consequently, the amount of lean body mass (FFM). The values of Xc depends on constituents of cellular membranes and from the interface among cells; therefore, its value is directly correlated to the cell density (i.e. to the hypertrophic, normotrophic or atrophic cell condition) and inversely to the integrity of cell membranes (Fields et al., 2012). R and Xc are significantly correlated to each other, both in normal and pathological conditions (Piccoli, 1998; Piccoli, Pittoni, Facco, Favaro, & Pillon, 2000; Piccoli et al., 1995): any physiological or pathological changes in R and/or Xc are proportionally related to each other. Phase angle (PA) is one of the BIVA parameters. Defined as the arctangent: $(Xc/R)\cdot 180°/\pi$, PA is related to functional and nutritional status of the subjects: normal values are considered when it is between 5 and 7° (although higher values can be normally reached in athletes). The influence of Xc and R in the determination of PA made this parameter tightly related to the intra- and extracellular fluids. Consequentially, PA is related to the integrity of the cell membranes as the correct balance of intra- and extracellular fluids is a direct consequence of the correct performance of the functions of the cell membranes. Therefore, the PA can give an overall evaluation of the body composition (Kyle, Genton, & Pichard, 2013; Norman, Stobäus, Pirlich, & Bosy-Westphal, 2012; Norman et al., 2010).

BIVA and PA are independent of body weight; they provide semiquantitative measures of lean mass, fat mass (FM) and body water, less influenced by variations in body fluids and cell mass tissue variations (Lukaski & Piccoli, 2012; Micheli et al., 2014), although some limitations in their application in children still persist (De Palo et al., 2000).

The use of BIA/BIVA in athletes is less validated than other settings. BIA cannot be a reliable tool for evaluating FFM in athletes (Matias, Santos, Fields, Sardinha, & Silva, 2012), although it can be used for total body water (TBW) evaluation in these individuals (Matias et al., 2013). In order to overcome limitations, proposed equations (Matias et al., 2016) for standardization of the BIA method had been recently formulated: the cross-validation pointed out an $R^2 = 0.91$ for TBW and $= 0.70$ for extracellular water (ECW), thus revealing higher values in reproducibility patterns for these techniques with no or minimum levels of biases when applied in different athletic subjects. The use of BIVA can actually overwhelm minimum impairments in BIA calculations. Literature studies (Koury, Trugo, & Torres, 2014; Micheli et al., 2014; Nescolarde, Yanguas, Medina, Rodas, & Rosell-Ferrer, 2011) used BIVA in athletes for assessing the variation in their body composition in relation to the kind of sport and the rate of training. The application of BIA/BIVA in children is less validated. Validation protocols for the standardization of such techniques in both neonates (Piccoli et al., 2002) and children (De Palo et al., 2000) had been proposed. Nevertheless, the application of such techniques in little athletes is challenging. Quiterio, Carnero, Silva, Baptista, and Sardinha (2009a, 2009b) and Sherriff, Wright, Reilly, McColl, Ness, and Emmett (2009) adopted bioimpedance analysis in children involved in exercise training in order to assess body changes during exercise, although no reproducibility calculation were performed. Despite some limitations, the use of BIVA in such subjects can be considered as a good tool, easy to perform, able to improve the compliance of little patients to medical evaluation, with extremely reduced costs and the possibility to use them everywhere, even in the setting of sportive structures.

The purpose of this study was to evaluate lean and FM in children involved in daily competitive sports when compared to sedentary controls. Furthermore, the use of conventional BIA and BIVA was used in order to identify daily differences in trophism and hydration. The final goal of this study was to evaluate the possible seasonal variations in trophism and hydration of trained young athletes after one-year follow-up.

Materials and methods

This study was performed between May 2013 and June 2014 and involved two groups of children aged 8–11 years: (1) competitive individuals attending swimming and gymnastics sports clubs in Apulia region (Italy); (2) 'control group' enrolling age-matched healthy children.

Informed consent was obtained from parents of each subject before enrolment. The study was performed in agreement with Declaration of Helsinki guidelines and approval was obtained from the local Ethic Committee.

The enrolment phase took one month: all competitive and healthy children were screened at study entry (*t0*), after 6 months (*t1*) and one year (*t2*).

At the *t0* and *t1*, we enrolled the following final sample:

- 190 children in the general population group (non-competitive), aged 8.2–10.5 years [median 9.3 years; 94 (49.5%) males and 96 (50.5%) females].
- 29 competitive children, aged 8.0–10.5 [median 9.5 years; 15 (51.7%) males and 14 (48.3%) females].

At *t2*, the final group was composed by 24 athletes aged 9.1–11.6 years [median 10.5 years; 11 (45.8%) males and 13 (54.2%) females].

Anthropometric evaluations

Children data were included as codes in our database in order to keep privacy. Birth dates, types of sport and the number of dedicated hours/week were collected. Height, weight and bioelectrical impedance parameters were measured by means of BIA 101 Akern device (http://www.akern.com/it/82-schede-tecniche/156-scheda-tecnica-101.html). The data from controls were obtained by trained nurses directly in the school in the morning, the subjects dressed in underwear; those from the competitive subjects were detected in different sports centres in the afternoon and before a training session (in order to avoid biases due to loss of fluids). A Seca 711 equipped with a height-rod Seca 220 properly calibrated was used. The measure of weight and height were performed by the same operator and by means of the same instrument (precision: 0.1 cm and 0.1 kg).

Subjects were judged as underweight, normal weight, overweight or obese in relation to BMI and age (Cole, Bellizzi, Flegal, & Dietz, 2000; Cole, Flegal, Nicholls, & Jackson, 2007).

Bioelectrical impedance vector analysis evaluations

All subjects/controls underwent Bioelectrical Impedance Vector Analysis (BIVA) evaluations. R and Xc derive from dedicated regression equations; in agreement with age, gender, weight and height, the software calculated TBW, ECW and intracellular water (ICW), FFM and FM (Kotler, Burastero, Wang, & Pierson, 1996). In order to overcome BIA limitations (Rush, Bristow, Plank, & Rowan, 2013; Wabitsch et al., 1996; Wells et al., 1999), the 'BIA Vectors' was used: R and Xc were standardized by height, as components of the impedance vector Z (Piccoli et al., 1995). Measures from different individuals were standardized by dividing the vector Z for the height: Z/h = (R/h and Xc/h) or Z/R = h/h + jXc/h (Foster & Lukaski, 1996; Kushner, 1992; Lukaski, 1996)[2]. The correlations between R and Xc, R/h and Xc/h determine the ellipsoidal shape of the distributions of bivariate probability (confidence intervals and tolerance). Each nomogram Biavector was compared with the vectors distribution of the reference population. Percentile curves at 50th, 75th and 90th percentile allow a semiquantitative evaluation of hydration on a 7-point ordinal scale (based on the three ellipses isodensity of probability and on the two verses of the major axis in any clinical condition). Similarly, by considering the intersection of percentiles curves along the minor axis (i.e. right-to-left axis), the nomogram Biavector allows us a semi-quantitative evaluation of changes in tissue trophism (hydrophilic interstitial cells and structural proteins). BIVA provided an estimation of the PA (PA = arctangent $[(Xc/R)^*(180°/\pi)]$), that is, the difference between the voltage and the intensity of current in a circuit.

All BIVA measurements were made by the same operator. Electrodes were placed on the left side of the body, specifically on the dorsal surface of the ankle and foot, at the midline level of the tarsus, and on left wrist and hand, at the midline level of the carpal joint at a distance of at least 5 cm. The children lay supine while R and Xc values were recorded. Data on body composition and FFM, FM, TBW, ECW, PA were extrapolated for each child using the software Body Gram Pro of Akern, after entering the values of Xc and R.

Hours/week of physical activity

The physical activity of the children was evaluated in terms of hours dedicated during a week. This was evaluated both in athletic and non-athletic individuals. The duration of exercise time in athletic children was assessed in relation to their activity during the pool staying. Hours/week evaluations in non-athletic children were evaluated in relation to the total time dedicated to usual physical activities. Therefore, these were compared to the parameters derived from BIA and, above all, BIVA.

Statistical analysis

Pearson's chi-square test was used to evaluate the independence of the relationship between the population groups (competitive and controls). Generalized linear models were applied to evaluate, both at *t0* and *t1*, the differences in age-adjusted weight, height and all parameters of bioimpedance between the two groups. The analysis was then stratified by gender, categories of BMI, type of sport and volume of weekly hours of physical activity. In order to assess longitudinal differences in body composition parameters among *t0*, *t1* and *t2* follow-ups, an analysis of variance for repeated measures was performed. *P*-values for paired sample comparison were adjusted for multiple comparisons using Tukey–Kramer's method. A p-value $< .05$ was considered statistically significant. The BIVA software (Piccoli A, Pastori G: BIVA software. Department of Medical/Surgical Sciences, Padua University, Italy, 2002) was used to plot the direct impedance measurements R/h and Xc/h as a bi-variate vector in a nomogram. The comparison between the vectors estimated in the two populations, both at the time *t0* and *t1*, stratified by sex, were carried out using ellipses of confidence, which represent the dispersion of 95%, and the Hotelling's T^2-test for independent samples. The software also calculated the distance of generalized Mahlanobis between the vectors, allowing obtaining a measure of the distance between the two groups that takes into account their variability.

Results

At *t0*, 54.73% of non-competitive (104/190) had heights higher than the 50th percentile, as compared to the 55.18% (16/29) in the competitive group; at *t1*, these percentages respectively rose to 62.10% (118/190) and 62.06% (18/29). No differences were detected in term of gender distribution as the number of male individuals were similar at t0 and t1 ($p = .741$ at *t0*, $p = .611$ at *t1*). Furthermore, there were no differences in term of BMI between the two groups, even after stratifying the two populations by gender (Table I).

The values of R and Xc at *t0* and *t1* and adjusted for age are shown in Table II. Both values were lower at *t0* in competitive individuals as compared to general population although only Xc values showed statistically significant differences. Nevertheless, at *t1* there was an increase in the values of both R and Xc in both groups, although only Xc still persisted to be statistically significantly lower in competitive individuals as compared to controls (49.40 ± 0.49 vs. 46.44 ± 1.25, $p = .028$). In particular, although R/h increased in both the competitive (+9.43) and non-athletes (+5.80) after 6 months follow-up, the difference between the two groups was not statistically significant ($p = .650$). On the contrary, the increase observed in competitive individuals' Xc/h (+3.28) was significantly higher than that observed in non-competitive (+0.66, p for difference: 0.011).

According to PA, this parameter was significantly lower in competitive when compared to non-competitive at *t0* (5.72 vs. 6.17, $p < .001$), and this difference was maintained even after 6 months ($p = .001$), although non-athletes showed a decrease in PA (−0.02) when compared to the increase in athletes PA (+0.37).

Interesting insights also came from the evaluation of BIA indicators (TBW, ECW and ICW) as the difference in *t0* and *t1* values of TBW/h showed a significant increase in non-athletes (+0.50 ± 0.13, $p < .001$) (Table II).

According to ECW/TBW ratio, this was significantly higher in athletes (43.03%) than in non-athletes (41.56%) at *t0* (Table II). After six months

Table I. Body mass index (BMI) variation at *t0* and *t1*.

Time	Sex	Body mass index			
		Non-competitive	Competitive	Difference (CI 95%)	*p*
T0	M	19.74	19.68	0.06 (−2.62, 2.74)	1.000
	F	19.06	17.68	1.38 (−1.36, 4.13)	0.562
	Tot	19.40	18.68		0.332
T1	M	20.08	19.65	0.43 (−2.39, 3.25)	0.979
	F	19.59	17.89	1.70 (−1.18, 4.59)	0.422
	Tot	19.84	18.77		0.173
T1–T0	Tot 1 – Tot 0	**+0.44**	**+0.11**		**0.043**

Notes: The numbers are expressed as mean (standard deviation) and number (range). CI, confidence interval; F, female; M, male; Tot, total population (male and female); Tot 1 – Tot 0, difference between 6 months follow-up and baseline.

Table II. Values of (resistance) r/h, (reactance) xc/h, total body water (TBW)/height (h), ECW/TBW in competitive and non-competitive at *t0* and *t1*: gender distribution

		R/h		
Time	Sex	Non-competitive	Competitive	*p*
T0	M	444.52 (6.76)	399.68 (17.00)	0.071
	F	464.94 (6.69)	465.00 (17.52)	1.000
	Tot	454.73 (4.76)	432.34 (12.21)	0.089
T1	M	442.60 (6.49)	412.19 (16.34)	0.312
	F	477.73 (6.45)	472.85 (16.81)	0.993
	Tot	460.17 (4.58)	442.52 (11.73)	0.163
		Xc/h		
T0	M	47.80 (0.66)	39.66 (1.66)	<.001
	F	49.73 (0.65)	46.41 (1.71)	0.269
	Tot	48.76 (0.46)	43.03 (1.19)	<.001
T1	M	47.05 (0.69)	42.66 (1.74)	0.090
	F	51.76 (0.68)	50.22 (1.79)	0.852
	Tot	49.40 (0.49)	46.44 (1.25)	0.028
		TBW/h		
T0	M	16.08 (0.23)	17.60 (0.58)	0.074
	F	15.03 (0.23)	14.86 (0.60)	0.994
	Tot	15.55 (0.16)	16.23 (0.42)	0.132
T1	M	16.63 (0.20)	17.86 (0.49)	0.097
	F	15.50 (0.19)	15.23 (0.51)	0.958
	Tot	16.06 (0.14)	16.54 (0.35)	0.209
		ECW/TBW		
T0	M	41.50% (0.28%)	42.65% (0.69%)	0.414
	F	41.62% (0.27%)	43.41% (0.71%)	0.089
	Tot	41.56% (0.19%)	43.03% (0.50%)	0.006
T1	M	41.00% (0.25%)	40.59% (0.64%)	0.936
	F	41.22% (0.25%)	42.22% (0.66%)	0.483
	Tot	41.11% (0.18%)	41.41% (0.46%)	0.543

Note: The numbers are expressed as mean (standard deviation).

follow-up, the proportion of water in the extracellular compartment significantly decreases ($p = .026$) in the two groups: $-0.45 \pm 0.19\%$ in non-competitive, $-1.63 \pm 0.49\%$ in competitive individuals. At *t1* an increase in ICW was detected, while a loss of water in the extracellular compartment was greater in competitive individuals when compared to non-competitive.

R, Xc and PA were also repeated after one-year follow-up for the group of competitive individuals. R/h values at *t2* were lower than *t0* in both genders. Same decreases were observed according to Xc/h and PA, although no statistically significant differences could be obtained (Table 1 suppl.).

The distributions of Biavector in competitive and non-athletes at *t0* had been compared each other and visually depicted in Figure 1. The differences in distributions between groups were statistically significant both in males ($p = .0001$) and females ($p = .0044$). At *t*1 a shift towards the top of the ellipse was observed for both in males and females although only the males displacement remained statistically significant ($p = .0077$), as those of females did not significantly differ between competitive and non-competitive ($p = .6472$) (Figure 1).

Variations in FFM and FM adjusted for height (h)

Table 2 suppl. gathers the data from the variations in FFM and FM both adjusted for height. The values of FFM/h estimated by the BIA software were greater in competitive when compared to non-athletes, as well as FM/h both at *t0* and *t1*, although no statistically significant difference was observed after the six months follow-up (Table 2 suppl.). As the population was composed of growing children, the lack of difference between *t0* and *t1* might be due to the parallel increase in lean/FM and their height.

Furthermore, at *t2* competitive individuals showed TBW/h and FFM/h in growing escalation when compared to values at *t1*. Although ECW percentage at *t1* was reduced when compared to *t0*, we observed an increasing trend at *t2* in females, while male individuals still continued to show ECW percentage lower than *t1* [data not showed].

Influence of hours/week of physical activity

At *t0*, the weekly hours dedicated to physical activity by non-competitive individuals ranged from a minimum of 0 to a maximum of 10 h (median = 2), while competitive individuals practiced sports from

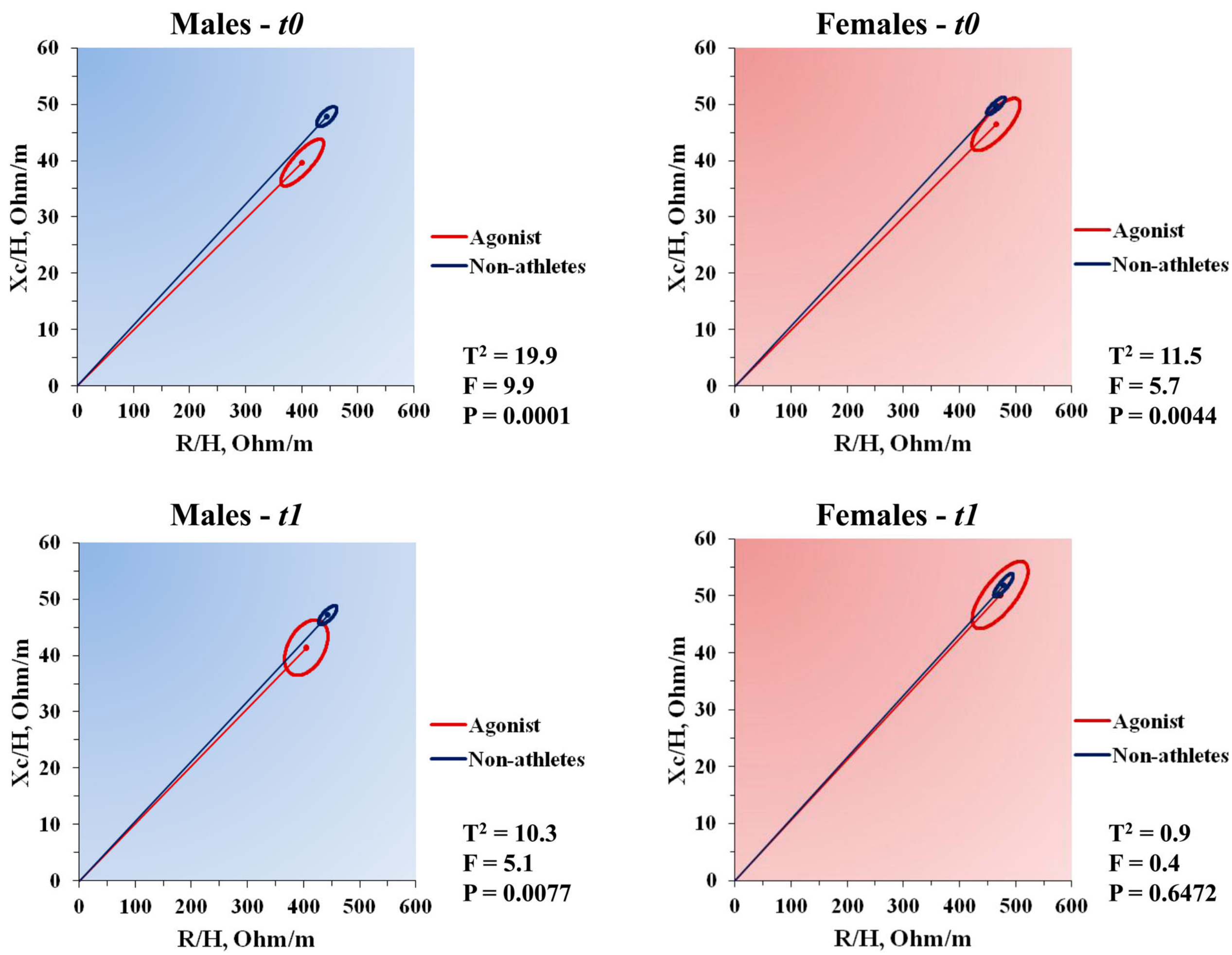

Figure 1. The distributions of biavectors in competitive and non-competitive athletes at *t0* and *t1*.

a minimum of 2 to a maximum of 20 h (median = 6.5). The differences between two groups is statistically significant ($p < .0001$).

At *t1*, the non-competitive maintained a range of hours/week of physical activity between 0 to 12 h (median = 2), while competitive constantly practiced 2–20 h/week (median increased to 8 h per week) and the differences between two groups is statistically significant ($p < .0001$) [data not showed].

Table III showed the number of hours of sport per week and their relation to FFM/h and FM/h. Statistical analyses outlined a significant and direct correlation of hours/week and FFM/h, while an inverse relationship was observed for FM/h according to the total of the population (competitive and non-competitive individuals). Nevertheless, when considering the populations as separate entities, the correlations lost their statistical significance.

Discussion

Our study tried to delineate the influence of competitive sports practice in body composition in children. The aim was to compare the body composition between healthy non-athletic and athletic young individuals by means of BIA evaluation, followed-up for at least one year. Poor data exist in the literature about the evaluation of such a purpose and, at least, most of them considered a limited number of parameters or did not involve control groups (Gutiérrez, Aldea, Cavia Mdel, & Alonso-Torre, 2015; Kalnina et al., 2015; Matias et al., 2016).

A first interesting insight in our analysis is the observation that BMI was not statistically different between competitive and non-athletes. The hypothesis is that the lean mass can influence the evaluation of BMI. Although at *t1* the increase in BMI was significantly higher in non-competitive when compared to competitive subjects (+0.44 vs. +0.10, $p = .043$), we think that this condition was better related to an increase in FM (as demonstrated by BIA measurements).

During the six months follow-up, male competitive individuals' R was significantly lower as compared to controls (Table II). This was probably due to an increase in body water and lean mass. According to

Table III. Hours/week of physical activity influence

	All subjects		Non-competitive		Competitive	
	Estimation	Pr > | *t* |	Estimation	Pr > | *t* |	Estimation	Pr > | *t* |
FFMH at *t0*						
• Hours/week	0.11	0.0186	0.11	0.2050	−0.01	0.9108
• Age	0.51	0.0484	0.20	0.4943	1.55	0.0026
• Sex (male)	0.79	0.0058	0.62	0.0430	1.30	0.0670
• BMI	0.46	<.0001	0.44	<.0001	0.71	<.0001
FFMH at *t2*						
• Hours/week	0.11	0.0044	0.09	0.2076	0.08	0.2697
• Age	2.69	<.0001	2.74	<.0001	2.31	<.0001
• Sex (male)	0.71	0.0036	0.59	0.0263	1.22	0.0276
• BMI	0.51	<.0001	0.49	<.0001	0.78	<.0001
FMH at *t0*						
• Hours/week	−0.13	0.0093	−0.09	0.3215	−0.03	0.6991
• Age	0.39	0.1289	0.66	0.0252	−0.45	0.2972
• Sex (male)	−0.57	0.0489	−0.43	0.1643	−0.91	0.1524
• BMI	1.05	<.0001	1.08	<.0001	0.79	<.0001
FMH at *t2*						
• Hours/week	−0.12	0.0008	−0.12	0.0875	−0.06	0.2743
• Age	−1.75	<.0001	−1.86	<.0001	−1.05	0.0007
• Sex (male)	−0.49	0.0362	−0.37	0.1503	−1.06	0.0093
• BMI	1.05	<.0001	1.08	<.0001	0.79	<.0001

Notes: BMI, body mass index; FFM, Lean body mass; FM, fat mass; FFMH, lean body mass corrected for height; H, both adjusted for height.

BIA evaluations, the values of TBW/h and FFM/h both at *t0* and *t1* were effectively higher for competitive. In particular, this was more pronounced in males because of a greater amount of muscle mass and lower amount of FM as compared to females. The presence of lower values of Xc/h in athletes either at *t0* to *t1* was probably related to the greater section of the limbs in this group (i.e. the conductor cross section) due to the greater musculature development caused by sports practice. Nevertheless, Xc/h is also proportionally determined by the cell density (impedance of the conductor) which was influenced by the percentage of intracellular water (rICW) (Chertow et al., 1995) estimated by BIA: we observed lower rICW values in competitive subjects, especially at *t0*. On parallel, even a sort of 'sufferance' of the muscle cell membranes caused by the intense and frequent exercises could negatively influence Xc/h, a hypothesis corroborated by the lower PA levels demonstrated at *t0* and *t2*. Such findings of PA values were similar to those coming from Koury et al. (2014) who studied adolescent competitive Brazilian football and basketball players. The hypothesis was that the over-training can influence PA because this parameter is related to the deterioration of the integrity and function of muscular cell membranes (Baumgartner, Chumlea, & Roche, 1998; Norman et al., 2010). The May–June period (i.e. *t0* and *t2*) are the periods preceding races and sportive events, thus athletes increase the intensity of the workload during this period. Furthermore, the young athletes arrive at such a period after a 10 months period of endurance. December–January (i.e. *t1*) are usually characterized by a daily training softer. Therefore, the increase in Xc/h from *t0* to *t1* in competitive subjects was significantly higher than in non-competitive probably in relation to the improvement in the muscular trophism with increased levels of intracellular proteins and glycogen which trigger increased intracellular body water levels (Ribeiro et al., 2014). Also rICW and PA increased from *t0* to *t1*: probably a reduced stress from the training can explain such results.

At *t2*, in training conditions similar at *t0*, the values of R/h in competitive individuals were lower than *t0* ones in both genders. The values of Xc/h were lower in females as compared to *t0*, while remained unchanged in males. Consequently PA at *t2* in females showed a decline as compared to *t1*, although still persisted higher as compared to *t0*; on the contrary, male values at *t2* increased as compared to *t1*. Lower R/h values might be related to the increase in FFMdue to the height and muscles growths. This was supported by the estimation of FFM/h, that is, the increase of FFMnormalized for height and by the increase in TBW/h which was considerably greater than TBW weight-adjusted. The different trend in Xc and PA reflected BIA measures: at *t2* females showed a mild decrease in rICW (and increasedpercentage of extracellular water), while males demonstrated a constant increase as compared to *t1*. These results mean that the return to a situation of increased workload (*t2*) induced a negative muscular trophism in females and a positive one in males. The small sample size limits the evaluation of the exact role of exercise and gender characteristics in the determination of such results. Nevertheless, a similar trend in Xc and PA at increasing training loads in few weeks was reported in adult Italian professional football players (Mascherini, Gatterer, Lukaski, Burtscher, & Galanti, 2015). There are no comparable results in literature as BIA and, above all, BIVA evaluations of athletic children have not been performed till now. Although Sardinha, Marques, Minderico, and Ekelund (2016 in press) recently observed a close, negative relationship between changing lifestyle from sedentary to training and waist circumference ($\beta = -1.11$, $p < .05$), trunk FM ($\beta = -0.21$, $p < .05$) and total body FM ($\beta = -0.48$, $p < .05$) in children, their research still use DEXA for their evaluations.

In relation to lower values in R/h and X/h, the distribution of competitive individuals' ellipses of BIVA vectors was positioned below and to the left of that of non-competitive. Similar results came from Koury et al. (2014). These authors also observed that adolescent and adult competitive subjects showed a distribution of the ellipses to the left of the graph but higher than the normal population, thus affirming that they had a better hypertrophic answer to higher workloads. Despite the involvement of young-adults in their research, Micheli et al. (2014) confirmed the observation of Koury et al. (2014) and finally observed that the greater the shift to the left and at the top, the higher the quality of the footballer, as these ones assumed characteristics allowing them to better answer to higher workloads.

The number of hours of sport per week was directly correlated to the FFM/h and inversely to the FM/h (Table III) when considering the entire population (competitive + non-competitive). However, when considering populations as separate groups, correlations between the number of hours of sport and FFM/h or FM/h were not statistically significant. In non-competitive subjects, this can be due to the slightly dispersed value of hours of physical activity weekly which results in a volume of sports not sufficient to cause a significant influence on these parameters.

Competitive showed volumes of sports activities more dispersed but generally high (median 6.5 h/week at *t0* and 8.0 h/week at time *t1*): therefore the lack of significance may be due to the influence that the amount of training could exert on the muscular hypertrophic process. These data seem to be comparable with those of literature (Bonaccorsi et al., 2009).

Conclusions

BIA and BIVA detected not significant differences in FFM and TBW between competitive and non-competitive children. The amount of body fat both in relation to the height and weight was significantly higher in non-athletes. The hours of sportive activity/week were directly related to the FFM/h and inversely to the FM/h. Reduced R/h in athletes suggested increased hydration, while the reduced Xc/h and PA values suggested increased size of the section of the limbs or at least a greater 'sufferance' in cell membranes in athletes when compared to non-athletes.

Seasonal variations had been observed in competitive subjects and they might be related to the different intensity in training and remoteness of summer breaks off.

Disclosure statement

No potential conflict of interest was reported by the authors.

Supplemental data

Supplemental data for this article can be accessed here http://dx.doi.org/10.1080/17461391.2017.1291750.

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