Original article

Body Components Differences and Their Impact of Phase Angle Values in Athletes and Non-Athletes

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Abstract

Introduction: The aim of this paper was to determine PhA values in athletes and sedentary population. The specific aim was to determine differences between subjects of the same sex and with a different level of physical activity, as well as the factors affecting PhA values.

Materials and Methods: Sixty-six athletes and sedentary students participated in the research. They were divided into four groups according to sex and level of physical activity. Routine BIA at 50 kHz was performed and BMI, PBF, FFM, PMM, TBW, ECW, ICV, ECW/ICE ratio, BMR, BM, PhA and impedance were measured.

Results: Male athletes had higher PhA values (6.85±0.5°) compared to male non-athletes (6.29±0.67°), female athletes (5.61±0.44) and female non-athletes (5.47±0.58°). Statistically significant differences were found in men (PhA p=0.004; ECW/ICE ratio p=0.002), but not in women. The highest positive correlation was found in ICW (ρ +0.71 p≤0.01), while the highest negative correlation was found in impedance (ρ -0.79 p≤0.01). PhA variance was mostly due to PMM (B=+0.44, p=0.002).

Conclusion: Differences found in male athletes and non-athletes may suggest the influence of physical activity, since the variance in PhA values was mostly due to PMM and a positive correlation with ICW.

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Introduction

During recent years, body composition measurements have been particularly important due to the obesity epidemic and related illnesses, such as cardiovascular diseases and metabolic and endocrine disorders (1). Such measurements can be useful to predict clinical outcomes in children and adults (2) and can be used to characterise physique changes during growth, aging and training. However, they sometimes require expertise regarding the measurement of skinfolds, girths and skeletal breadths (3). Other methods used to asses body composition, such as computed tomography (CT), CT body composition (CTBS), magnetic resonance imaging (MRI), ultrasound (US) or dual-energy X-ray absorptiometry (DEXA), may not always be available or an appropriate choice (1). Cost-efficient, non-invasive and simple assessment of body composition and hydration status remains an important need, which is why bioelectrical impedance (BIA) is widely used (4, 5). BIA is considered superior even to some serum (albumin, transferrin) or anthropometric indicators (weight change, arm muscle circumference, triceps skin-fold thickness) (6, 7).

BIA measures the electrical characteristics of the human body either at 50 kHz or at several frequencies ranging from 1 to 1,000 kHz (5). It is the only method that allows for keeping track of body hydration and cell mass using the phase angle (PhA) and impedance (8). Although the PhA does not indicate body composition, but gives information on tissue capacity, cell size and cell membrane integrity, it correlates with cell mass, nutrition and general health both in children and adults and provides information on tissue resistance, which depends on lean body mass hydration (2). PhA is obtained by measuring the ratio between impedance (R) and reactance (Xc) based on the following equation (6):

$$PhA = Xc/R \times 180/\pi$$

Impedance is defined as a reduction in voltage due to the passage of current through the ionic solution of the body, while reactance is a delay in the passage of current measured as a phase shift. Both measures suggest cell function (9), correlate with body shape and influence the difference in the size and function of the body (3). Also, in adults, it is significant in the prognosis of the outcomes and mortality of haemodialysis, cancer, acquired immunodeficiency syndrome and cirrhosis patients (2).

According to Bosy-Westphal et al. (10), gender and age are the main determinants of the PhA in healthy adults, with men and younger people having higher PhA values (10). As far as body mass is concerned, the PhA increases with an increase in BMI to the value of 40 kg/m^2, after which it shows a negative correlation (10). In addition to age and gender, FFM and height have the strongest influence on PhA values, while the ECW/ICW fluid ratio shows a correlation with the PhA in a clinical environment and obese people (11). Body composition assessment in sports may be useful for estimating total body water (TBW) and FFM, sport performance and effects of a training program (5), whereas higher values of the PhA may be linked to a higher level of physical activity (12). The potential of the PhA and bioimpedance on the whole lies in the fact that it allows for non-invasive tissue monitoring, especially of hydration (1), and it can help with recommendations concerning the volume and intensity of training in sports (13).

The general aim of this paper was to determine PhA values in younger adult athletes and sedentary population. The specific aim was to define which body components the subjects of the same sex, but with a different level of physical activity differ in, as well as which body components relate to the PhA the most. Our hypothesis was that athletes will have higher PhA values than non-athletes. Also, we expected differences between subjects of the same sex, but with a different level of physical activity.

Materials and Methods

The research was performed at the College of Applied Sciences “Lavoslav Ružička” in Vukovar in June 2017, during the competition season. A total of 66 student volunteers, including active male and female athletes and male and female non-athletes living a sedentary lifestyle, participated in the research. The inclusion criteria for the athletes were the following: 1) age < 35 years, 2) no medical problems according to self-reported information, 3) no smoking or alcohol abuse according to self-reported information, 4) participation in 3-5 training sessions per week and 5) involvement in organised sport activities. The inclusion criteria for the non-athletes were the following: 1) no medical problems reported 2) age < 35 years, 3) no smoking or alcohol abuse reported. Subjects were divided into four groups – male athletes – MA (26 subjects), female athletes – FA (8 subjects), male non-athletes – MNA (22 subjects) and female non-athletes – FNA (10 subjects). The most common men's sports were football and handball, whereas the most common women's sports included handball and volleyball.

The aim of the research and the procedure of BIA measurement was explained to the students. All subjects granted their informed consent for routine BIA and the research was carried out in accordance with the Declaration of Helsinki for medical research involving human subjects. The subjects arrived at 8:00 AM for the BIA exam, on an empty stomach and with an empty bladder. The measurement was performed in a standing position. The students were barefoot, wearing shorts and a T-shirt, with their hands held out and away from the body, feet slightly apart. Prior to the measurement, the participants were advised to sit for 10 minutes (equilibrium period). Earlier on, they had been instructed not to drink alcohol eight hours and not to consume any food four to six hours prior to the measurement. Also, the subjects did not do any physical activity the day before the measurement. Regarding room preparation, the examination was conducted in a lit up, pleasantly air-conditioned room (22 °C). Machine preparation included verification in accordance with the manufacturer's instructions. The measurement was conducted on the TANITA MC-780MA body mass analyser (TANITA Corporation, 1-14-2, Maeno-cho, Itabashi-ku, Tokyo, Japan, 2013).

Height was measured to the nearest 0.1 cm using a stadiometer (Seca, Hamburg, Germany). PhA and impedance were measured using BIA, as well as other body components: BMI, percent body fat (PBF), FFM, TBW, extracellular water (ECW), intracellular water (ICW), extracellular water/intracellular water ratio (ECW/ICW ratio), percent muscle mass (PMM), bone mass (BM) and basal metabolic rate (BMR).

Statistical analysis

Results are presented as mean ± SD. Normal distribution of data was evaluated using the Shapiro–Wilk test. Differences between all four groups were determined by the Kruskal–Wallis H independent samples test. Statistical significance was determined at the $p \le 0.001$ level. The post hoc Mann–Whitney U test with Bonferroni correction was done to establish the differences between male athletes and non-athletes and female athletes and non-athletes. Statistical significance was set at the $p \le 0.03$ level. The Spearman's rank correlation coefficient (ρ) was used to determine the correlation between the PhA and other variables. The Stepwise-Backward regression was applied in order to determine which variables influenced the PhA the most. Statistical significance was confirmed at the $p \le 0.05$ level. Statistical analysis was performed using the IBM SPSS Statistics 23 software (Business Machine Corp, 2015) independently by the authors.

Results

Body composition results for all four groups are presented in Table 1. The highest PhA values were found in male athletes and the lowest in female non-athletes. Female non-athletes had the highest PBF and male athletes the lowest PBF. The PMM and FFM were the highest in male athletes and the lowest among female non-athletes. Impedance was the highest in female non-athletes, and TBW, as well as ICW and ECW, were the highest in male athletes.

Table 1. Values of variables for male and female athletes, male and female non-athletes and for the entire sample

		Age	Height	BMI	PBF	FFM	TBW	ECW	ICW	ECW/ICW ratio	PMM	BM	BMR	Impedance	PhA
MA	$\bar{X}$	20.38	184.34*	23.39*	14.49	67.82*	48.87*	18.91*	29.96*	.63	64.45*	3.37*	8462.00*	558.69	6.85*
	Nr.	26	26	26	26	26	26	26	26	26	26	26	26	26	26
	SD	1.20	7.65	2.70	4.55	8.26	5.48	1.93	3.61	.03	7.87	.38	1094.69	52.35	.50
MNA	$\bar{X}$	20.82	181.22	23.68	16.89	63.96	46.13	18.35	27.78	.66	60.78	3.18	8003.90	586.09	6.29
	Nr.	22	22	22	22	22	22	22	22	22	22	22	22	22	22
	SD	2.36	6.65	3.83	5.96	7.27	4.81	1.75	3.14	.03	6.93	.34	946.15	60.19	.67
	p	0.97	0.08	0.80	0.16	0.16	0.14	0.46	0.052	0.002**	0.16	0.16	0.21	0.17	0.004**
FA	$\bar{X}$	21.63*	172.38	21.33	23.44	48.58	35.03	14.38	20.65	.69	46.11	2.46	6237.38	697.88	5.61
	Nr.	8	8	8	8	8	8	8	8	8	8	8	8	8	8
	SD	3.93	11.12	2.36	3.67	8.46	5.96	2.69	3.29	.02	8.04	.41	981.47	97.81	.44
FNA	$\bar{X}$	20.00	165.70	21.59	25.32*	44.23	31.90	13.25	18.65	.71*	41.99	2.24	5781.50	750.10*	5.47
	Nr.	10	10	10	10	10	10	10	10	10	10	10	10	10	10
	SD	.82	8.25	2.15	3.73	5.98	4.21	1.90	2.36	.03	5.69	.29	698.68	94.04	.58
	p	0.36	0.27	0.90	0.27	0.07	0.07	0.27	0.055	0.32	0.07	0.08	0.17	0.27	0.63
Total	$\bar{X}$	20.62	179.03	22.96	18.02	60.63	43.71	17.32	26.39	.66	57.60	3.02	7633.52	613.70	6.31
	Nr.	66	66	66	66	66	66	66	66	66	66	66	66	66	66
	SD	2.08	10.26	3.11	6.33	11.82	8.29	2.95	5.39	.04	11.26	.59	1417.75	98.39	.77
	p	0.74	0.000†	0.09	0.000†	0.000†	0.000†	0.000†	0.000†	0.000†	0.000†	0.000†	0.000†	0.000†	0.000†

*the highest values; **statistical significance $p \leq 0.03$ †statistical significance $p \leq 0.001$

(MA – male athletes; FA – female athletes; MNA – male non-athletes; FNA – female non-athletes; $\bar{X}$ – arithmetic mean; Nr. – number; SD – standard deviation; p – statistical significance; BMI – body mass index; PBF – percent body fat; FFM – fat free mass; TBW – total body water; ECW – extracellular water; ICW – intracellular water, ECW/ICW ratio – extracellular water/intracellular water ratio; PMM – percent muscle mass; BM – bone mass; BMR – basal metabolic rate; PhA – phase angle

ECW/ICW ratio was the highest among female non-athletes and the lowest among male athletes. The amount of BM was the highest in male athletes and the lowest in female non-athletes. Male athletes had the highest BMR. Statistically significant differences between the male subjects existed only in the ECW/ICW ratio (p=0.002) and PhA values (p=0.004). As far as the female subjects are concerned, whether athletes or those leading a sedentary lifestyle, there were no statistically significant differences (p>0.03). Regarding the correlation between the PhA and other variables, there was a positive correlation with height (ρ +0.35 p=0.004), BMI (ρ +0.55 p≤0.01), FFM (ρ +0.64 p≤0.01), PMM (ρ +0.64 p≤0.01), TBW (ρ +0.66 p≤0.01), ECW (ρ +0.58 p≤0.01) and ICW (ρ +0.71 p≤0.01), BM (ρ +0.63 p≤0.01) and BMR (ρ +0.64 p≤0.01) and a negative correlation with PBF (ρ -0.35 p=0.004), ECW/ICW ratio (ρ -0.78 p≤0.01) and impedance (ρ -0.79 p≤0.01). Regression analysis showed that PhA values were mostly influenced by PMM (B=+0.44, p=0.002), BMI (B=+0.31, p=0.000) and impedance (B=+0.004, p=0.03), which describes almost 83% of the variance in the values of the PhA (R^2=0.83).

Discussion

PhA is a good prognostic indicator in numerous clinical conditions of patients suffering from HIV, bacterial infection, liver cirrhosis, kidney disease, tuberculosis and cancer, but little is known about PhA values in healthy individuals (6). According to Selberg and Selberg (8), PhA values over 5.4˚ are considered normal, in the range of 4.4˚ to 5.4˚ as borderline and under 4.4˚ as abnormal (8). Lower values usually indicate a cell integrity disorder or even cell death (14). In this research, PhA values of male athletes were 6.85±0.5˚, female athletes 5.61±0.44˚, male non-athletes 6.29±0.67˚ and female non-athletes 5.47±0.58˚. A potential explanation may be that higher PhA values are present in physically active people (15), but in the absence of sport-specific reference values, we can only use general healthy population values as references and hypothesise on the influence of physical activity (16). In their systematic review on bioelectrical impedance phase angle in sports, Di Vincenzo et al. (5) stated that PhA values have been shown to be significantly associated with muscle strength and physical activity and to vary between sexes and with age (5). Since the PhA is considered a simple indicator of muscle mass and is defined by tissue hydration and cell membrane potential (8), and since ECW/ICW ratio is one of the measures that influences PhA variability, changes in PhA values usually correlate with cell size, cell permeability and differences in fluid distribution in various tissue types (11). Lower PhA values are caused by an increase in the ECW/ICW ratio in patients with inflammatory conditions and obese individuals (11). Male athletes in our research had the lowest values of the ECW/ICW ratio and PBF among all four groups and the highest values of FFM and PMM. We also found statistically significant differences in PhA values and the ECW/ICW ratio between male athletes and non-athletes. However, no such differences were found among the female subjects, which may be due to PBF values. According to Gallagher et al. (17), PBF of healthy women aged 20-39 ranges from 21% to 33% and of athletes from 14% to 20% (18). On the other hand, female athletes in this research had PBF values of 23.44±3.67%, while female non-athletes had PBF values of 25.32±3.73%, with a mean difference of 1.88±0.06%, placing them in the same reference category. We found a strong positive correlation between the PhA and ICW, TBW, FFM, PMM, BMR, BM, ECW and BMI, as well as a strong negative correlation with impedance and the ECW/ICW ratio. Differences in the distribution of fluids, an increase in the amount of ECW and a compensatory increase in the ECW/ICW ratio may be leading to a decrease in PhA values (11). Increase in the ECW/ICW ratio leading to a decrease in PhA values may be connected to PBF because adipose tissue influences haemodynamics or fluids (11), although in our research, PBF showed a moderate correlation to the PhA. Higher ICW content in physically active people may be a reflection of physiological cellular adaptations leading to higher PhA values (12). Genton et al. (12) hypothesised that physically active people practice carbohydrate loading to improve performance and consequently have higher ICW content to store glycogen (12). Silva et al. (19) state that regardless of body composition changes, athletes who increase reactance and resistance reduce ECW, while those who raise PhA increase ICW (19). The correlation with FFM and PMM may be explained by the fact that the PhA is directly related to the amount and function of cell membranes, in this case, muscle cells (6). As for BMI, it explained 31% of the variance in PhA values and according to Bosy-Westphal (10), an increase in PhA values with an increase in BMI only occurs with a BMI of about 40 kg/m^2 and is just a reflection of an increased number of muscle or fat cells (10). BMR also showed a positive correlation with the PhA, which may be linked to greater amounts of FFM in athletes (20). Regarding BM, we found no evidence explaining a moderate positive correlation with the PhA, except that it may be due to the age of the participants. Negative correlation of the PhA with impedance may be due to sex. Men tend to have lower values of impedance than women (15) due to a higher amount of FFM and lower PBF. Our results are only applicable when using a BIA device operating at a single frequency (50 kHz), which can be a limiting factor. For a better estimate of the influence of body components on the PhA, the BIA measurement should be performed in different frequency ranges (5 kHz, 50 kHz, 100 kHz) (15). Another limiting factor is that we had no record of the nutritional status of the subjects. Moreover, regarding the medical condition of the students, we relied on self-reported information. A small sample size may also be a limitation, even though the student athletes played different sports.

In conclusion, PhA values in this research were higher in athletes than in non-athletes and higher in male athletes compared to female athletes. We found significant differences in PhA values and the ECW/ICW ratio between male athletes and non-athletes, but no such differences were found in the female subjects. Variables showing the highest positive correlation with the PhA were ICW, TBW, FFM and PMM, indicating a possible influence of physical activity. Regression analysis in this research showed that the variance in the PhA is mostly influenced by PMM, BMI and impedance.

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