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BODY COMPOSITION AND REGIONAL PHASE ANGLE AS INDICATORS OF VO_{2max} IN ELITE MALE AND FEMALE COMBAT ATHLETES

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Abstract

Various potentially related factors, such as maximal oxygen consumption (VO_{2max}) and anthropometric, physiological, genetic, and chronotype data, can contribute to athletes' training programs. Therefore, this study examined the relationship between bioelectric impedance analysis (BIA), phase angle (PhA) values, and aerobic power in female and male combat athletes. PhA, lean mass (kg), fat mass (kg), and body fat percentage (%) values of the athletes were measured using the BIA method. Oxygen consumption (VO_2) was measured using a mobile cardiopulmonary exercise test system. Statistical tests included analyses of bivariate correlation, t-tests, and multiple regressions. All parameters differed except for male and female athletes' age and training experience. Male athletes have higher maximal oxygen consumption (VO_{2max}) and PhA values than female athletes. BIA and PhA were differentially (small-medium) associated with absolute and relative VO_{2max} in all athletes ($p<0.05$), whereas no correlation was found between both PhA and relative VO_{2max}, respectively. The relationship between PhA and VO_{2max} is more revealing, especially in male and female athletes. PhA and BIA have the potential to be used in the field by conditioning and trainers to assess aerobic endurance swiftly; this can aid in determining competition readiness, training progress, and monitoring the recovery of muscle performance following injury.

Keywords: Body Composition, Regional Phase Angle, Aerobic Endurance, Elite Combat Athletes

Introduction

Changes in body composition are associated with athletic performance (Campa et al., 2020). Lean mass gain is for the development muscle power and strength. On the other hand, losing weight improves cardiovascular fitness agility, and speed (Silva, 2019). However, since BIA is affected by hydration and physical activity, there needs to be a clear recommendation regarding the accuracy of using this method in athletes (Deutz et al., 2019). The commonly used BIA examines the electrical properties of the human body either at 50 kHz (single-frequency BIA) or at many frequencies in the range of 1-1000 kHz (multifrequency BIA and BIS = bioimpedance spectroscopy). Impedance is the body's resistance to an alternating current. It is caused by reactance (Xc), which is related to the capacitance component of tissues, including cell membranes and tissue interfaces, and resistance (R), which relates to the current flowing through tissue containing water and electrolytes. PhA, also known as the arctangent of the Xc to R ratio, is a term used to describe the angular shift (phase difference) between voltage and current sinusoidal waveforms. In humans, the current reaches its maximum/minimum peaks at regular intervals after the voltage (positive PhA values), and cell membranes and tissue interfaces most likely cause this lag (Di Vincenzo et al., 2019a).

For this reason, recent studies on athletes have begun focusing on the PhA instead of BIA. It has become a widely used method for evaluating athletes' body composition and cellular health and is used in the general population (Toselli et al., 2020). It is accepted that cell function increases as PhA increases. PhA is also associated with muscle mass, an essential determinant of muscle tissue functionality, and physical adaptations obtained after training or nutritional interventions (Cunha et al., 2018; Tomeleri et al., 2019). Furthermore, the literature emphasizes the positive relationship between phase angle and sport-specific muscle strength (Lukaski and Raymond-Pope, 2021; Martins et al., 2021). Therefore, PhA may be a viable way to measure muscle quality in athletes, according to a recent systematic review, which added data on general muscle tissue functionality and performance to the literature (Di Vincenzo et al., 2019b). It is known that PhA is significantly related to muscle strength (Mundstock et al., 2019) and varies according to gender (Barbosa-Silva et al., 2005). In a study with male cyclists, muscle mass increased as muscle PhA increased; In female volleyball players, it was found that handgrip strength increased as PhA increased (Di Vincenzo et al., 2020; Pollastri et al., 2016). Veitia et al. reported that male athletes in artistic gymnastics, weightlifting, wrestling, and rowing had higher PhA values of ≥7 than other athletes. In artistic gymnastics, weightlifting, and rowing, female athletes had higher PhA values of ≥6.5 than other female athletes (Di Vincenzo et al., 2020). Although it is known that PhA is highly variable among athletes, there is no clear information about phase angle values by sport category. For this reason, it is crucial to do sports-specific studies. Studies on aerobic power, BIA, and PhA have reported possible mechanisms for a direct relationship between these parameters (Langer et al., 2020). The term "body cell mass" refers to the metabolically active cell mass that takes part in processes such as the intake of oxygen, the production of carbon dioxide, and the expenditure of energy. It is believed that body cell mass is directly related to aerobic power. PhA was highly linked with running performance in a study examining the association between PhA and endurance performance (Genton et al., 2020).

Various potentially related factors such as VO_{2max} and anthropometric, physiological, genetic, and chronotype data can contribute to athletes' training programs. As a result, this study aims to investigate the connection between the values of BIA and PhA and the aerobic power of male and female combat athletes. The characteristics of body composition measures related to athletic performance and aerobic power may be easier for trainers. We hypothesize that a higher phase angle is related to better VO_{2max} İn Combat Athletes.

Material and Method

Participants and study design

Two hundred ninety-two athletes (147 men, 145 women) from combat sports (judo-karate-taekwondo) trained at the Turkish Olympic Preparation Center and voluntarily agreed to participate in this study. Accordingly, ethical approval was obtained by the Non-Interventional Medicine Ethics Committee of Gazi University Faculty of Sport Sciences on 08.02.2022 (Reference number: 286499). The inclusion criteria were; Be over 18, have at least three years of strength training history, be a licensed athlete, and not have additional problems affecting training performance. Exclusion criteria were: Having any discomfort that will affect the measurements on the dates of the tests, having trained at high intensity within two days prior to the measurements, unexpected discrepancies during measurements, and Voluntary withdrawal of the participant from the research. From the designated universe G-Power program for calculating sample size (Faul et al., 2009), our study planned the sample group as 290 combat athletes. The current cross-sectional survey study was conducted in a single period.

Bioelectrical Impedance Analysis (BIA)

The athletes' phase angle, body fat percentage, lean mass, and fat mass values were measured using the BIA (MC 980; Tanita Corp.,1000 kHz, Japan) after 12 hours of fasting. With the help of hand and foot electrodes in the device, the electric current passing through the body provides a comprehensive body analysis. The head-to-leg (H-L) value shows the electric current passing through the whole body from hand to foot and the phase angle value of the whole body. The leg-to-leg (L-L) value shows the electric current passing from foot to foot and the phase angle values of the lower extremity.

VO_{2max}

Oxygen consumption (VO_2) was measured with a portable cardiopulmonary exercise test (Cosmed K5, Italy Serial No: 2019030706) system, which is capable of automatic gas analysis from each expiratory air, with a ramp protocol (Scheer et al., 2018) on the treadmill. Before each test, the portable metabolic gas analyzer was calibrated using a sample of recognized gases (5.0% CO_2 and 16.0% O_2). In order to eliminate the adverse effects of room conditions on performance and oxygen consumption data during the tests carried out in the laboratory environment, the temperature was 18-23°C, and the relative humidity was below 70% with air conditioners. Participants warmed up at 8 $km.h^{-1}$ for 4 min. Then, the running speed progressively increased by 1 $km.h^{-1}.min^{-1}$ until volitional exhaustion. The achievement of VO_{2peak} was identified as the plateauing of VO_2 (<2.1 $mL.kg^{-1}.min^{-1}$ decrease) despite an increase in workload (Poole and Richardson, 1997). Regarding the data obtained from the VO_{2max} test, Absolute VO_{2max} is simply the amount of oxygen breathed in litres per minute. Relative VO_{2max} measures weight in litres per minute per kilogram of body weight.

Statistical analysis

The data were analyzed using SPSS 22.0 (IBM Corp, Armonk, NY, USA), and the results were presented as mean ± standard deviation. Data normality was verified using the

Kolmogorov-Smirnov test**.** The relationship between PhA, BIA, and VO_{2max} parameters was investigated using a preliminary bivariate correlation analysis. VO_{2max}, BIA, and PhA variables were compared using the independent samples t-test to control the values of men and women. Gender-specific multiple regressions evaluated whether the phase angle and body composition were associated with the VO_{2max}. The alpha level was set at 0.05 for all the analyses. Cohen's d was used to compute effect sizes for the independent samples t-test, which were then categorized according to Hopkins.

Findings

Table 1. Body composition, phase angles, absolute and relative VO_{2max} test performance

	Men Mean-SD	Women Mean-SD	All Mean-SD	p	d
n	147	145	292		
Age (yrs.)	20.70 ±3.39	20.57 ±2.09	20.13 ±2.09	0.07	0.10
Experience (yrs.)	6.78 ±2.39	6.35 ±1.22	6.07 ±1.81	0.09	0.12
Body weight (kg)	75.71 ±14.93	62.48 ±8.66	69.14 ±13.89	0.00	1.08
Body Mass İndex (kg/m2)	24.32 ±3.69	22.88 ±2.05	23.60 ±3.07	0.00	0.48
Body fat (%)	12.992 ±5.55	19.85 ±5.32	16.40 ±6.42	0.00	1.26
Muscle Mass (kg)	65.21 ±10.40	47.37 ±5.71	54.84 ±11.21	0.00	2.12
VO_2 (mL/kg/min)	56.04 ±9.43	46.32 ±7.39	51.22 ±9.77	0.00	1.14
Phase Angle (H-L)	7.02 ±0.65	6.38 ±0.57	6.70 ±0.69	0.00	1.04
Phase Angle (L-L)	7.09 ±0.76	6.48 ±0.64	6.79 ±0.76	0.00	0.86

H-L; Head to leg, L-L; leg to leg

BIA, PhA, and VO_{2max} are contain in Table I. All parameters differed except for male and female athletes' age and training experience. Male athletes have higher VO_{2max} and PhA values than female athletes.

Table 2. The matrix of correlations body composition, phase angles, and VO_{2max} variables

Gender		Age (yrs.)	Body weight (kg)	BMİ	Body fat (%)	Muscle Mass (kg)	Phase Angle (H-L)	Phase Angle (L-L)
Male	VO_2 (mL/kg/min)	**-0.553***	**-0.638**	**-0.598***	**-.0498***	**-0.553***	-0.106	0.085
Female	VO_2 (mL/kg/min)	**-0.436***	**-0.434***	**-0.496***	**-0.346***	**-0.440***	**0.303***	**0.135***

*p < 0.05

The matrix of correlations includes body composition, phase angles, and VO_{2max} variables Table II. BIA and phase angle were differentially (small-medium) associated with VO_{2max} in both men and women athletes ($p < 0.05$).

Table3. Linear regression analysis independent variables and VO_{2max} performance.

	Age (yrs.)	Body weight (kg)	BMİ	Body fat (%)	Muscle Mass (kg)	Phase Angle (H-L)	Phase Angle (L-L)	Adjust R2
VO_{2max}								
Model 1	**-0.249***	1.320	-0.061	**-0.878***	**-1.389***	-0.093	**0.233***	0.50
Model 2	**0.159***	1.055	**-0.757***	-0.144	-0.867	**0.288**	**0.153***	0.37
Model 3	**-0.123***	**1.097***	**-0.531***	**-0.657***	-0.857	0.103	**0.249***	0.41

All values represent standardized β's.
Model 1 male athletes
Model 2 Female athletes
Model 3 All athletes
*p < 0.05.

According to the results of linear regression analysis (Table 3); Model 1; age, body fat, muscle mass, and L-L were determined as strong predictors in VO_{2max} ($p<0.05$). Model 2, age, BMI, H-L, and L-L were determined as strong predictors in VO_{2max} ($p<0.05$). Model 3, age, body weight, BMI, and L-L were strong predictors in VO_{2max} ($p<0.05$).

Discussion and Conclusion

The relationship between one's body composition and one's level of athletic performance is an essential area of research in sports science, particularly for highly skilled athletes who train frequently and intensively. Our study shows that BIA, phase angles head to the leg, and phase angles leg to leg obtained from 1000 kHz bioelectrical impedance analysis highly correlate with VO_{2max} value in female and male athletes. The relationship between the angles and VO_{2max} is more revealing, especially in male athletes than in female athletes. According to this study, men athletes had a higher phase angle regardless of sport modality than women athletes. These findings are consistent with previous studies on the general population and former athletes (Matias et al., 2021; Mattiello et al., 2020).

A high phase angle may represent regular physical activity, as superior physical performance usually results from training. In addition, two recent systematic reviews discovered a connection between phase angle and physical activity (Di Vincenzo et al., 2019b; Mundstock et al., 2019). So far, the relationship between BIA, PhA, and VO_{2max} has yet to be studied in different categories of male and female athletes. Similarly, longitudinal studies in non-athletes revealed that implementing a physical activity program increased PhA (Langer et al., 2019). In addition, several cross-sectional studies on specific sports indicate that elite athletes have a more significant phase angle, muscle mass, and a lower fat percentage than less-trained competitors. However, the sport-influencing phase angle is debatable (Di Vincenzo et al., 2019b). This evidence strongly suggests that the link we observed in our study between a high BIA, PhA, and a higher VO_{2max} is explained by regular physical exercise.

Excess fat mass in sports affects endurance performance, whereas an increase in lean mass, particularly muscular mass, is related to greater power and strength (Campa et al., 2019).

Furthermore, determining localized body composition allows detecting changes in muscle mass and strength between different body sections, which may lower the risk of damage (assessment of contralateral limbs, agonist-antagonists (Ackland et al., 2012). When sprinting 2000 meters, Yoshiga and Higuchi (Yoshiga and Higuchi, 2003) discovered that fat-free mass (FFM) negatively correlated with time. This finding, which may be explained by the positive effects that increased FFM has on aerobic performance, is referred to as the inverse time-FFM relationship (Mujika et al., 2016; Silva, 2019). Because athletes' PhA and BIA values alter throughout the season, the BIA readings must be as detailed and informative as possible to provide proper body composition and physical fitness monitoring. Changes in body composition caused by the accumulation of fat could have a negative impact on the athletic performance of athletes or even cause them to compete in a heavier category, which would drastically reduce their performance in Olympic combat sports, where athletes compete in clearly defined weight categories. For example, an analysis of the anthropometric profiles of top karate competitors found that the proportion of body fat for men ranged from 7.5 to 18.6 per cent. In comparison, the body fat percentage for women was 18.6 per cent (3.2 per cent) (Chaabene et al., 2012).

In addition, participants in recent research of high-level karate competitors had a fat percentage of 18.6 (4.0 per cent), according to the study's findings (Rossi, 2019). Studying the relationship between body composition and phase angle in athletes of various sports modalities, including Olympic combat sports (OCS) (judo and karate), Marini et al. discovered similar values to those found in this study for karate athletes, with statistically significant differences between men and women: PhA was 7.7 (0.8) degrees for men and 6.8 (0.8) degrees for women (n=63) (Marini et al., 2020). For instance, in judo, the phase angle is related to magnesium status and can be used indirectly to measure muscle function. Furthermore, muscle function is linked to health, and as a consequence, athletic performance is affected by these factors (Matias et al., 2015).

In earlier research, various populations were found to correlate with levels of PhA and measures of muscle strength and aerobic fitness (da Silva et al., 2018; Gerken et al., 2021; Yamada et al., 2019) and because the relationship between PhA and muscle strength increased athletes' VO_{2max} values. Although a direct link between PhA and aerobic fitness has yet to be demonstrated, PhA has been linked to the number of cells in the body, the metabolically most active component capable of giving incredible energy and physical performance (Dittmar et al., 2015). Muscle tissue contains more significant quantities of water and electrolytes and is a good conductor with higher resistance values. (Mulasi et al., 2015). Strength training causes muscle hypertrophy, which leads to increased reactance (Ribeiro et al., 2018). Studies analyzing the relationship between PhA and muscle strength and aerobic fitness used different variables because the latter two can be influenced by body size (e.g., height, diameters, circumferences), components (e.g., muscle tissue), biological variables (sexual maturation), and lifestyle factors. Although age and gender have been identified as determinants of the divergence in the association between BIA, PhA, and VO_{2max} (Garlini et al., 2019), studies looking at the relationship between PhA and muscle strength and aerobic fitness used different methods (Zeiher et al., 2019). PhA levels increase with age in both sexes in the general population until late adulthood, when they begin to fall (Koury et al., 2014; Torres et al., 2008). However, a growing gap between the sexes continues to widen through adolescence, and males have mean levels that are consistently higher than females by the time they reach adulthood (Barbosa-Silva et al., 2005). Veitia et al.used BIA to evaluate 943 Cuban athletes who competed in 26 sports. Males had a substantially higher (+15.5 per cent) mean PhA score than girls, with a difference for most sports studied (Veitia et al., 2017). In conclusion, a recent study on 202 athletes competing in 11 different sports was carried out by Marini and colleagues. The researchers found that the mean PhA was higher in males than in females (+ 13.2 per cent) (Marini et al., 2020). No data were available for comparing boys and females who competed in the same sport. According to our research, this rate was 9.11 per cent for the phase angle head to leg and 8.60 per cent for the phase angle leg to leg.

Recent research finds that regional BIA at the lower limb level provided essential information in soccer and cycling populations when PhA was studied regionally in female and male athletes. This information was gleaned from soccer players and cyclists. While Whole Body PhA did not change throughout the 2012 Giro d'Italia (Giorgi et al., 2018), Lower Body PhA (LPhA) decreased during a three-week stage race, according to a study of cyclists participating in the race (Marra et al., 2016). These figures allude to the gender difference, with male athletes having greater lower limb PhA values than female athletes (Mascherini et al., 2017). However, the application of regional PhA indicates athlete performance in many categories has yet to be determined. As the regression analysis results reveal, when assessing athletes' VO_{2max}, it can be highly informative to consider body composition values determined using population-specific equations in addition to PhA.

In light of the findings from this study, future research is encouraged to further explore the intricate relationship between body composition, phase angle, and VO2max across a broader spectrum of sports and athletic disciplines. Such investigations should aim to refine our understanding of how these variables interact to influence athletic performance, with a particular focus on developing gender-specific insights that can lead to more personalized and effective training and nutrition strategies. Additionally, the potential of regional phase angle measurements as a precise tool for assessing muscle quality and predicting athletic readiness warrants deeper examination. Embracing these areas of research will not only enhance the practical application of body composition and phase angle assessments in sports settings but also contribute to the broader knowledge base in sports science, ultimately benefiting athletes' training, recovery, and performance outcomes.

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