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Original

Phase angle is moderately correlated with lower-body power and fitness capacity in junior Badminton players

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ABSTRACT

Objective: Phase angle (PhA) is derived from bioimpedance analysis (BIA) and is widely used as an indicator of cellular health, cell membrane integrity, and cell function. Lower-body power and fitness capacity are of paramount importance in success in several sports, including badminton. This study aimed to evaluate the relationship between PhA and lower-body power and fitness capacity in 22 junior badminton players (14 males, 8 females, 17.7 ± 1.4 years old).
Methods: Bioelectrical impedance was used to assess body fat (BF), muscle mass (MM) and PhA. Countermovement jump test and Yo-yo intermittent test level 2 were used to evaluate lower-body power and fitness capacity, respectively. Pearson's correlation was used to assess the relationship between PhA and lower-body power and fitness capacity, with multiple regressions considering the effect of BF, MM, and age.
Results: PhA exhibited a positive relationship with lower-body power ($\beta = 0.48$; $p < 0.02$) and fitness capacity ($\beta = 0.37$; $p < 0.04$). However, these relationships lost significance after adjustment for the co-variables MM, BF, and age ($p > 0.24$).
Conclusion: PhA is associated with lower-body power and fitness capacity in junior badminton players. However, these relationships are influenced by MM, BF, and age co-variables.
Keywords: Aerobic; Anaerobic; Athletes; Bioimpedance analysis; Body composition.

Ángulo de fase se correlaciona moderadamente con la potencia de los miembros inferiores y la condición física en jugadores de Bádminton junior

RESUMEN

Objetivo: El ángulo de fase (AF) se deriva del análisis de bioimpedancia (BIA) y es usado ampliamente como indicador de la salud celular, la integridad de la membrana celular y la función celular. La potencia de los miembros inferiores y la condición física son de gran importancia para el éxito en varios deportes, incluido el bádminton. El objetivo de este estudio fue evaluar la relación entre el AF y la potencia de los miembros inferiores y la condición física en 22 jugadores de bádminton junior (14 hombres, 8 mujeres, 17.7 ± 1.4 años).
Método: Se utilizó la bioimpedancia eléctrica para evaluar la grasa corporal (GC), la masa muscular (MM) y el AF. La prueba de salto en contramovimiento y la prueba YoYo de recuperación intermitente nivel 2 fueran utilizados para evaluar la potencia de los miembros inferiores y la condición física, respectivamente. Se calculó la Correlación de Pearson para evaluar a relación entre el AF y la potencia de los miembros inferiores y condición física, con regresiones múltiples considerando el efecto de GC, MM y edad.
Resultados: AF mostró una relación positiva con la potencia de los miembros inferiores ($\beta = 0.48$; $p < 0.02$) y la condición física ($\beta = 0.37$; $p <0.04$). Sin embargo, estas relaciones perdieron significación después de ajustadas con las covariables MM, GC y edad ($p > 0.24$).
Conclusión: El ángulo de fase se asocia con la potencia de los miembros inferiores y la condición física de jugadores de bádminton juveniles. Sin embargo, estas relaciones son influenciadas por las covariables masa muscular, grasa corporal y edad.
Palabras-clave: Aeróbico; Anaeróbico; Deportistas; Análisis de bioimpedancia; Composición corporal.

Ângulo de fase está moderadamente correlacionado com potência dos membros inferiores e aptidão física

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em jogadores juniores de Badminton

RESUMO

Objetivo: O ângulo de fase (AF) é derivado da análise de bioimpedância (BIA) e é amplamente usado como um indicador de saúde celular, integridade da membrana celular e função celular. A força dos membros inferiores e aptidão física são de grande importância para o sucesso em vários esportes, incluindo o badminton. O objetivo deste estudo foi avaliar a relação entre a AF e a potência dos membros inferiores e a aptidão física em 22 jogadores juniores de badminton (14 homens, 8 mulheres, 17,7 ± 1,4 anos).

Método: A bioimpedância elétrica foi utilizada para avaliar gordura corporal (GC), massa muscular (MM) e AF. O teste de salto com contramovimento e o teste intermitente Yo-yo nível 2 foram usados para avaliar a potência dos membros inferiores e a aptidão física, respectivamente. Correlação de Pearson foi usada para avaliar a relação entre AF e potência dos membros inferiores e aptidão física, com regressões múltiplas considerando o efeito do GC, MM e idade.

Resultados: AF exibiu uma relação positiva com a potência dos membros inferiores ($\beta = 0.48$; $p < 0.02$) e aptidão física ($\beta = 0.37$; $p < 0.04$). No entanto, essas relações perderam a significância após o ajuste para as covariáveis MM, GC e idade ($p > 0.24$).

Conclusões: AF está associado à dos membros inferiores e à capacidade física de jogadores juniores de badminton. No entanto, essas relações são influenciadas pelas covariáveis MM, GC e idade.

Palavras chave: Aeróbio; Anaeróbio; Atletas; Análise de bioimpedância; Composição corporal

Introduction

Badminton is a racket sport characterized by actions of short duration and long intensity, in combination with short resting time. It is a highly demanding sport, with an average heart rate of more than 90% of the maximal HR of the player and utilizes both aerobic and anaerobic systems (approximately 70 and 30%, respectively). Moreover, the sport demands high levels of lower-body power for jumping, moving, and covering the court.[1] High lower-body power plays a huge role in success in sports as it is associated with improvements in jumping, sprinting, and agility performance.[2] Vertical jump height is regarded as one of the most important parameters in many different sports, as they can be used to measure muscular performance of the lower limbs.[3] Similarly, aerobic and anaerobic fitness are key for optimal physical performance in several sports, including badminton.[4] The countermovement jump (CMJ) has been widely used to measure the reactive power of the lower limbs as it includes the eccentric component to the jumping movement,[5] whereas the Yo-yo intermittent test is commonly used to evaluate aerobic and anaerobic performance in athletes.[6]

Body composition may affect an athlete's potential for success for a given sport as it can influence an athlete's speed, endurance, and power, whereas body composition can affect an athlete's strength, and agility. A body with greater muscle/fat ratio is often advantageous in sports where speed and muscle power are involved.[7] Bioelectrical impedance analysis (BIA) is a non-invasive method for estimating body composition and nutritional status. The phase angle (PhA) is one of the parameters derived from the BIA, and is wide used as an indicator of cell membrane integrity.[8] It reflects the relationship between resistance, the pure opposition of tissues to the passage of electrical current, and reactance, the resistive effect produced by the interface of tissues and cell membranes.[9] Moreover, PhA has been pointed as an index of water distribution between the intracellular and extracellular compartments, not only for the general population but also among athletes.[10] It has been reported that PhA may be used to assess muscle intracellular mass and composition in untrained people,[11] as well as muscle tissue integrity,[12] quality and vitality of cells,[13] hydration status,[14] and intensity efforts[15] in athletes. Similarly, PhA has already been reported to be associated with cardiorespiratory fitness in adults,[16] as well as physical conditioning and body composition in children.[17] However, most of these studies did not investigate the effect of confounding factors which could interfere in the PhA evaluation, such as muscle mass, body fat, or age. Moreover, the relationship between PhA and lower-limb power and fitness capacity is yet to be investigated.

Therefore, the aim of this study was to assess the relationship between PhA and lower-body power and fitness capacity in badminton junior athletes considering the influence of muscle mass, body fat, and age.

Methods

Participants

This is a cross-sectional study carried out in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Universidade Federal do Piauí under protocol number 2.552.506. A convenience sample composed of 22 junior elite badminton players (14 males, 8 females) aged 17.7 ± 1.4 years old was used in this study. All athletes played for the Brazilian national badminton team, trained badminton 6 sessions per week for at least 1 year, and competed in events sanctioned by the Brazilian Badminton Confederation. Athletes were contacted by referral from coaches or sporting federations. The criteria for inclusion in the study were individuals who trained with competitive objectives, participated in regional, national or international events, and had hours of weekly training equal to or greater than 6 h. Demographic (age and sex) and training volume information was obtained through a questionnaire. All volunteers were previously notified about the experimental procedures. Participants signed assent forms and parent/guardians of the underaged volunteers provided informed consent, according to resolution 466/12 of National Health Council (Brazil). Subjects with any known chronic-degenerative disease, users of any anti-hypertension medicines, or who presented any physical adversity that would impair their maximum performance were excluded from this investigation.

Study design

The investigation was carried out during the pre-season preparation in two stages. On the first day, the individuals were anthropometrically evaluated, underwent the BIA for PhA evaluation and performed the CMJ test. On the second day, after 48 hours, the participants performed the Yo-yo endurance test (Level 2) in order to evaluate their fitness capacity. The tests took place at the Sports Center from Federal University of Piauí, Brazil. The volunteers were instructed to refrain from exercises for 48 hours before the experiment procedures and to avoid the intake of protein-rich foods, caffeine and alcohol during this period. The experimental design is shown in Figure 1.

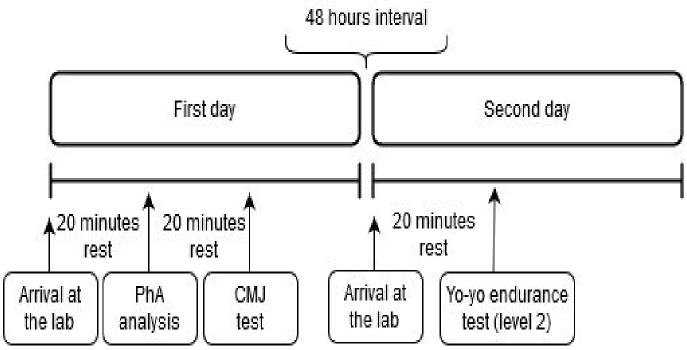

Figure 1. Schematic view of the procedures protocol. PhA, phase angle; CMJ, countermovement jump.

Anthropometry and phase angle evaluations

Body mass was assessed using a calibrated electronic scale (Tanita Solar Scale®, Brazil; 0.1kg). Height was measured using a stadiometer (0.1cm) attached to the wall (Wiso®, Brazil). The volunteers were asked to wear light clothes and no shoes. Body mass index was calculated by dividing the body mass in kg by the square of the height in meters.

Percentage body fat (%bf) and muscle mass (MM) were estimated using a bioelectrical impedance device (Inbody ®S10, Seoul, South Korea), previously validated by Fujii et al.[18] PhA was calculated as arc-tangent(reactance/resistance) × 180 °/π at a single frequency (50kHz). Before the measurements, the athletes were oriented to remove all metallic objects. They were instructed to lie in a supine position, with hands pronated and legs abducted. The skin region was cleaned with alcohol and the electrodes were placed in accordance with the manufacturer's instructions. The participants were instructed to refrain from intaking food and drink 4h, strenuous exercise 24h, and alcohol or caffeine consumption 48h prior to the measurements.

Lower-limb power evaluation

The height of the CMJ test was measured using the contact mat Jumptest® (Hidrofit Ltd, Brazil), connected to the software Multisprint® (Hidrofit Ltd, Brazil). The device has already been validated as a reliable tool to assess vertical jump performance.[19] All testing sessions were preceded by a 5-min standardized warm-up and all players were familiar with the test procedures. They were oriented to maintain their hands on their hips in upright standing position. Starting from orthostatic posture, they were instructed to flex their knees (approximately 90º) as fast as possible and immediately jump as high as possible in order to activate the SSC. They kept their hands on their hips in order to avoid interference of the arm swing on the jump performance. Knees and ankles were completely extended from the moment of the take-off to the landing. They were also asked to keep their heads facing forward at all times. The volunteers performed each jump type 3 times and all values were registered. There was a rest interval of 60 seconds between each jump repetition.[20] The mean of the jumps was used for the statistical analysis.

Fitness capacity evaluation

The fitness capacity was assessed with Yo-yo endurance test level 2. Participants were instructed to run out and back on a 20-meter course, with the required speed increasing at set intervals until they were unable to continue.[6] VO_2max (ml/kg/min) was estimated using the equation:

- $24.4+6\times[\text{final speed}(km/h)]$ (for athletes aged >18 years old)
- $31.025+(3.238\times[\text{final speed}(km/h)])-(3.248\times age)+1.1536\times(\text{final speed}\times age)$ (for athletes aged <18 year).[21]

Statistical Analysis

Descriptive statistics are presented as mean and standard deviation. Data distribution was tested using the Shapiro-Wilk test. Standard error of measurements (SEM) was used to verify the reliability and Pearson's correlation was used to analyze the correlation between independent variables (PhA) and dependent variables (lower-body power and VO_2max). Multiple regression analysis was carried out to further test whether PhA is related with performance parameters, after adjusting for potential covariates, namely percentage body fat, muscle mass, and age. In all regression analyses, residuals were tested for normality. For all statistical analyses, significance was accepted at $p < 0.05$. The entire data analysis was performed using SPSS software version 20.0 (SPSS, Inc., Chicago, IL, USA).

Results

The general characteristics of the participants are described in Table 1. In the same table, the results of the tests of fitness capacity and CMJ can be seen. The athletes had mean values of BMI and %BF compatible with normal weight.

Table 1. Characteristics of the subjects

Variable	Mean ± SD	SEM
Age (years)	17.7 ± 1.4	0.61
Weight (kg)	62.1 ± 13.0	5.83
Height (cm)	170.4 ± 10.0	4.48
BMI (kg/m^2)	21.8 ± 1.7	1.41
BF (%)	16.3 ± 6.6	2.59
MM (kg)	30.0 ± 6.2	2.76
PhA (50 kHz)	7.7 ± 1.1	0.49
VO_2max (ml/min/kg-1)	40.6 ± 2.1	0.95
VVO_2max (km/h)	13.5 ± 1.3	0.58
CMJ height (cm)	37.7 ± 8.2	3.68

SD, standard deviation; SEM, standard error of measurements; BMI, body mass index; BF, body fat; MM, muscle mass; PhA, Phase angle; VO2max, maximal oxygen consumption; VVO2max, velocity at maximal oxygen consumption; CMJ, countermovement jump.

A moderate positive correlation was observed between PhA and CMJ height, and VO_2max (Figure 2). On the other hand, correlations of %BF were inverse and strong both for VO_2max ($r = -0.73$, $p < 0.01$) and for CMJ ($r = -0.76$, $p < 0.01$). Moreover, MM correlated positively in a high way with VO_2max ($r = 0.66$, $p < 0.01$) and very high with CMJ ($r = 0.75$, $p < 0.01$).

The multiple regression analyses between PhA and VO_2max are displayed on table 2. Three adjustment models are presented for body fat, muscle mass, and age. The correlation observed in the bivariate analysis was remained in the multivariate analysis of the regression ($\beta = 0.37$, $p < 0.04$), but this correlation did not prove to be independent of body composition (fat mass or muscle mass) or age.

The same behavior was observed when the relationship between PhA was related to CMJ in the multivariate analysis (table 2). A relationship was found between these two variables ($\beta = 0.48$, $p < 0.02$), but this relationship was not maintained when considering the covariates for body composition and age.

Discussion

The novelty of this study is that PhA was moderately associated with lower-body power and fitness capacity, which play key role in badminton performance. However, this relationship lost significance in models adjusted for body fat, muscle mass, and age. This suggests that the correlation between PhA and performance

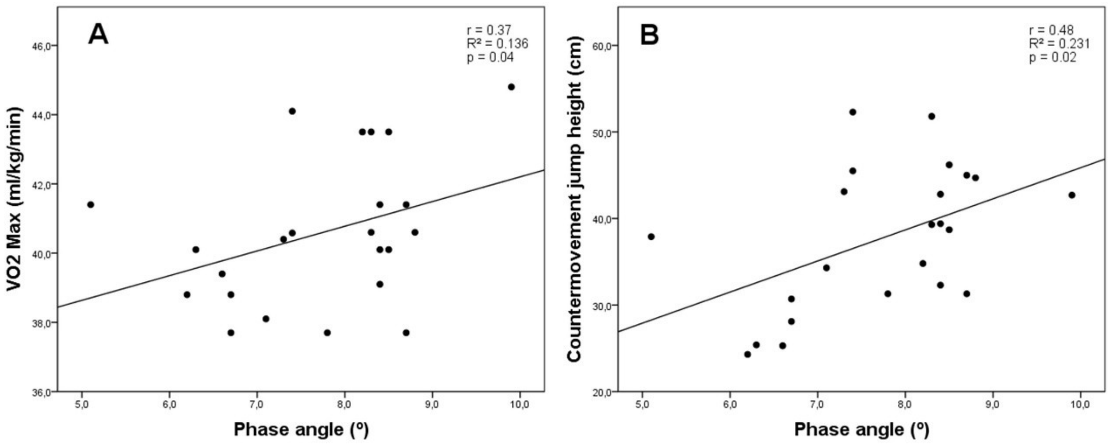

Figure 2. Pearson's correlation between phase angle and VO2max (Panel A) and countermovement jump performance (Panel B).p < 0.05.

Table 2. Influence of body composition and age in the association between PhA and fitness capacity and lower-body power

Independent variable	R^2	β	95% confidence interval	p-value
Phase angle and fitness capacity association				
Phase angle	0.14	0.37	-0.102–1.528	0.04
Model 1	0.53	0.69	-0.551–0.818	0.69
Model 2	0.60	-0.17	-1.186–0.520	0.42
Model 3	0.62	-0.17	-1.188–0.522	0.42
Phase angle and lower-body power association				
Phase angle	0.23	0.48	0.614–6.570	0.02
Model 1	0.61	0.19	-1.025–3.829	0.24
Model 2	0.68	-0.07	-3.453–2.418	0.72
Model 3	0.72	-0.07	-3.336–2.302	0.71

Linear regression with three models. Model 1: adjusted for percentage body fat; Model 2: adjusted for percentage body fat and muscle mass; Model 3: adjusted for percentage of body fat, muscle mass, and age.

is due to the muscle mass of these athletes. PhA is a novel prognostic factor already largely used in clinical context,[23] as well as in several sports disciplines, including volleyball,[24] soccer,[15] and swimming.[25] In spite of the crescent interest of researchers regarding PhA and sport performance,[15] the number of studies with specific sport disciplines, including badminton, is still scarce. Moreover, the majority of the studies assessing the relationship between PhA and performance does not take into consideration the adjustment for confounding variables. To the best of our knowledge, this is the first study to investigate this relationship in badminton players accounting for the effect of confounding factors.

The participants of this study presented similar values to the players of the Brazilian junior badminton team regarding age (17.7 vs. 16.2, respectively), height (170.4 vs. 168.1, respectively), body weight (62.1 vs. 64.7, respectively), and PhA height (37.7 vs 33.7, respectively). However, the volunteers of our study presented lower VO_2max (40.6 vs 46.3, respectively) when compared to national team players.[2]

While body composition and PhA are derived from the same BIA test, our findings indicated that PhA has a moderate association with performance. This is particularly important because PhA indicates a functional aspect of a primary body composition test, as the integrity state of the muscle tissue is determinant to its functioning.[26]

Body composition had stronger associated with fitness capacity and lower-body power than PhA. However, this information should be considered with caution. During the competition season, body composition may remain unchanged as the training results are stabilized.[27] Inversely, the integrity of the muscle tissue can alter in response to the training sessions and competition. Thus, PhA is an important variable for the assessment of sport performance regarding fitness capacity and lower-body power.

The positive correlation between PhA and power of lower limbs found in our investigation corroborates with a previous study.[15] The authors found a moderate association between PhA and short-term maximal intensity efforts in soccer players (β = 0.66; p < 0.001). However, the relationship remained significant even after adjustment for the co-variables fat-free mass and %BF (β = 0.52; p = 0.02), while the analysis in our investigation lost statistical significance using similar model (muscle mass and %BF). PhA values alter depending on the cell composition and water volume of the tissues, as well as its membrane potential.[28] Low PhA values indicate low resistance and reactance vectors, showing decrease of the cell integrity,[8] whereas high PhA values present high resistance and reactance vectors, related to a higher amount of intact cell membranes, which suggests an adequate health state.[28] Due to these technical implications, we consider that the PhA varies in relation to the integrity of the muscle tissue, which can be affected by extensive training load and eccentric exercise.[29]

This study was limited to a cross-sectional design, which does not allow establishment of a cause-effect relationship. It is noteworthy that this study was carried out during the pre-season training. Thus, these results may differ during the in-season period. Considering the methodological precautions taken before the data collection, we assume that the volunteers had no signs of muscle soreness. However, we suggest that the PhA and functional capacities evaluations should be conducted several times during the training season. This would be important to compare the stages of more and less training load and competition in order to verify possible influence of the state of physical demand in the association assessed in this study. The participants of the study were male and female badminton players, which may affect the homogeneity of the sample. In spite of these limitations, a strong point of this study is the adjustments for potential confounders in the association between PhA and aerobic and anaerobic parameters.

The main practical implication of this study is that PhA has a moderate relationship with lower-limb power and fitness capacity in junior badminton athletes. This opens the possibility of using the BIA-derived PhA as a new tool to evaluate lower-limb and fitness capacities. Therefore, PhA can play an important role in training load control, as it can be used to estimate aerobic and anaerobic capacities in junior badminton athletes. In addition, BIA is remarkably more accessible, simple to use, and affordable than similar lab-based devices. Further studies with greater sample size and other sport disciplines are suggested.

In conclusion, the results of this study indicate that PhA is associated with lower-body power and fitness capacity in junior badminton players. However, this relationship is influenced by muscle mass, percentage body fat, and age. Thus, PhA can be used as a prognostic estimator for physical performance.

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