Journal of Medical Devices Technology Vol. 2, No. 1, (2023) 6-11

Journal of Medical Devices Technology

jmeditec.utm.my

Original Research

Bioimpedance for Analysis of Body Composition in Sports

Mohd Riduan Mohamad [1,2*], Alshamrani Omar Ali H[1]

[1] Department of Biomedical Engineering & Health Sciences, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia
[2] Bioinspired Device & Tissue Engineering Research Group, Department of Biomedical Engineering and Health Sciences, Faculty of Electrical Engineering Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

ARTICLE INFO

Article History:
Received 29 October 2022
Accepted 28 February 2023
Available online 30 May 2023

Keywords:
Bioimpedance,
Body Compositions,
Phase Angle,
Sports

ABSTRACT

Phase angle (PhA), a bioelectrical impedance analysis (BIA) parameter, has proven to be a proxy of body cell mass in athletes, but very few data are available on its segmental evaluation (upper and lower limbs). Therefore, the aim of this study is to assess whether whole-body and segmental PhA varied among elite male athletes of different sports and compared these to control groups. Additionally, this study plans to investigate its relationship with body composition parameters. Elite athletes practicing cycling, football (soccer) players, MMA players, and weightlifters considered as active subjects collected from February 2021 till August 2021 age of 18–35 years undergo BIA measurements using Bio-impedance Analyzer BIA450 of BIODYNAMIC®, USA, from the UTM facility. PhA (whole-body and upper and lower limbs) will be considered as raw BIA variable. A total of 24 participants were studied, with 12 participants as active group (athletes and sports) as 12 participants as inactive (control group). Data were also compared with healthy subjects with similar characteristics who were serving as inactive subjects. Both whole-body and limb PhA are significantly higher in active participants (athletes) compared to their respective control group (inactive participants). The average value of PhA for the active and inactive are 7.1 and 6.87, respectively. PhA was found to be positively correlated with BMI and fat-free mass (FFM) more in athletes than in controls and FFM were considered as the main determinant. Furthermore, the direct evaluation of PhA can be used as a marker of survival in different sports and physical activities while predicting the injury and health risk associated with certain physical activities.

INTRODUCTION

Body composition (BC) evolutions, an important indicator of physical fitness and health in athletes, are essential for the careful monitoring and observation of obesity class, nutritional status, training outcomes and general health. In contrast with the general body mass, BC is analytically more consistent with active mass (lean body mass (LBM), body cell mass (BCM), muscle mass (MM), intracellular water (ICW), phase angle (PhA)) and inactive mass (fat mass (FM).

In sports context, athletes often and unanimously consider the assessment of Body Composition (BC) as a relevant and reliable means to improve their performance as well as to differentiate with various competitive set of levels, skills, and sports. Body composition (BC) assessment also provides relevant information in prevention of injuries and BC profile of athletes from different sports. Evaluation of BC in young and adult athletes is characterized by various growths and physiological factors which may influence the physical capacities and athletic performance affecting various physical systems of the athletes. Changes of fat free mass (FFM) and fat

* Mohd Riduan Mohamad (mohd.riduan@utm.my)
Department of Biomedical Engineering & Health Sciences, Faculty of Electrical Engineering, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia.

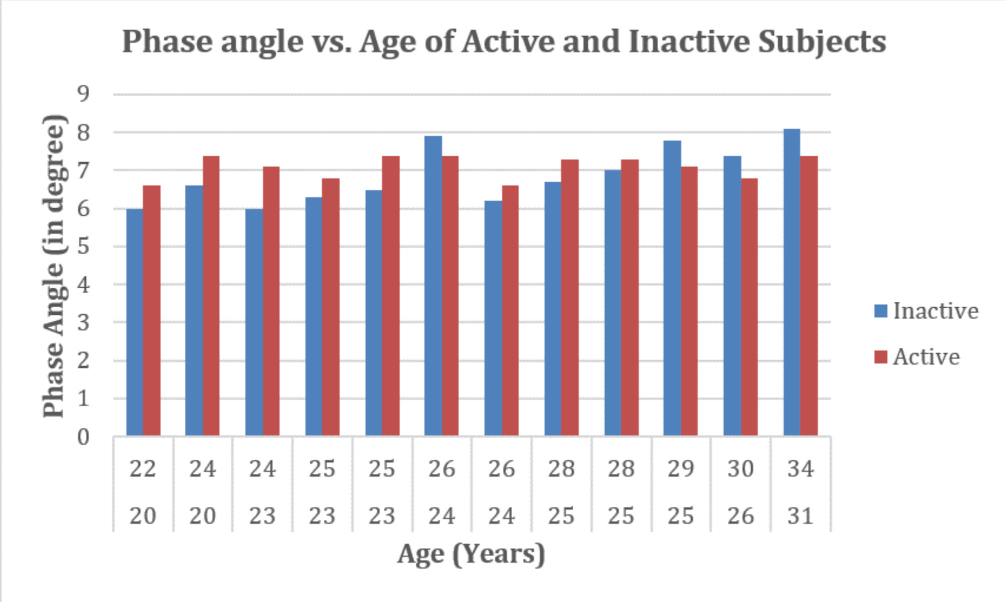

Fig. 1 Phase Angle vs. Age in Active and Inactive Subjects

mass (FM) are found to be depended on sexual and somatic maturation for athletes in sports (Giorgi et al. 2018).

Phase angle (PhA) is a raw BIA (bio-impedance analysis) variable that has been gaining attention in recent years because it is supposed to be an index of the ratio between extracellular and intracellular water, body cell mass, and cellular integrity. Theoretically, the use of PhA or Impedance Ratio (IR) may be crucial in evaluating athletes' body composition because it can provide useful data on the percentage of BCM in FFM in both cross-sectional and longitudinal studies. The BIA method has been used in healthy children and PhA is associated with cardiorespiratory fitness and FFM, showing the importance of promoting health behavior related to exercise in childhood (Kushner, 1992). BIA can differentiate the degree of body fat and body cell mass in individuals. Malnutrition and training mechanisms have a strong impact on PhA in athletic individuals (Di Vincenzo et al., 2019). PhA may provide a strong indication of muscle strength between different types of sports. PhA values may be significantly positively correlated with body mass index of the athletes in different training groups of sports. PhA BIA analysis could be an indication of the performance improvements or injuries or both. PhA analysis could also be useful in assessment of chronic and inflammatory diseases in clinical study. BIA is a safe, cheap, and easy method of measuring body composition.

In this context, as further studies have been published since then and considering the need to clarify the association between PhA and maturational status, the aim of this study was to investigate the relationship between PhA from BIA and muscle strength of the active and inactive participants during the movement control order (MCO) of COVID-19 in Johor Bahru, Malaysia. Though, there have been many studies in western and European countries among the athletes and different sports, there have been very little to no investigation for the healthy male adults regarding the effects of phase angle on their muscle strength and other BIA variables. This study successfully revealed that PhA significantly influence the muscle strength and other BIA variables in the active and control (inactive) participants.

MATERIALS AND METHOD

This study has been accomplished and carried out in three main phases which are briefly described as follows:

Phase 1: This phase deals with preparation of subjects and calibration of the devices for the accurate measurements.

Phase 2: In this phase of research, the raw data of the BIA measurements was collected for the athletes and control group as well as measuring the PhA for each subject.

Phase 3: This is the final phase of the project, and the statistical analysis will be performed and the study endpoint by drawing statistical inference of the analysis.

Subjects

In the present study, a total of 12 active participants were retrospectively analysed data of elite athletes practicing cycling, football (soccer) players, MMA players, and gymnasts (weight lifters), collected from February 2021 till August 2021 were performed. However, also 12 inactive participants were studied as the control group. Active subjects with the following inclusion criteria: males, age between 18-35 years, and at least 10-15 hours of training a week; while inactive subjects with the following inclusion criteria: males, age between 18-35 years, and no specific hours of training per week, were selected for this study (Martins et al. 2021). Subjects affected by metabolic and/or endocrine diseases and/or regularly taking any medications or using any drugs were excluded for both active and inactive group. Data of athletes was compared to healthy non-athletic males, who should serve as controls. Data from endurance cyclists of the Pro Cyclists of University Teknologi Malaysia (UTM), Johor Bahru, was collected during the same period of time. Football players were supposed to train and play in UTM football grounds during the weekends for 2—3 hours at

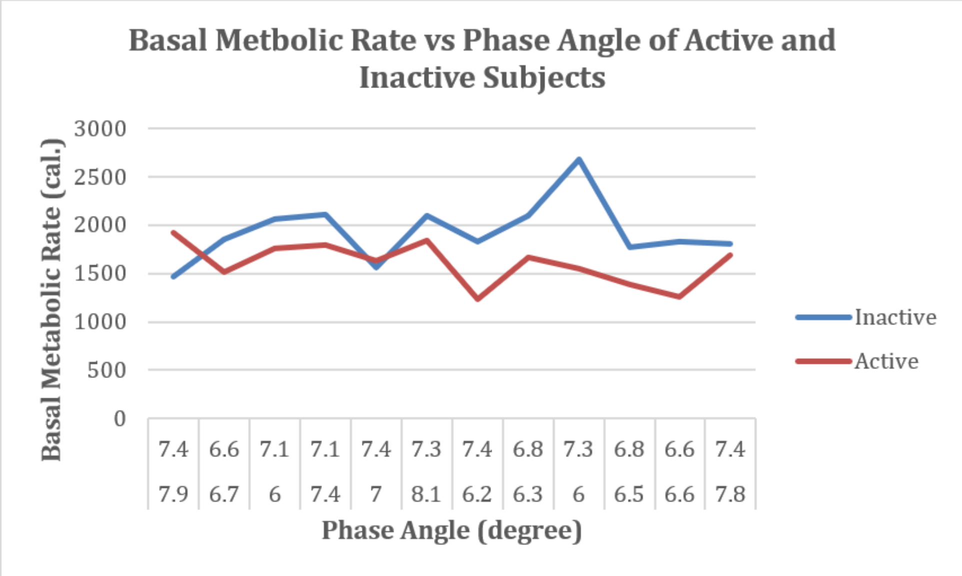

Fig 2. Basal Metabolic Rate vs Phase Angle in (Active and Inactive).

the same period of time. MMA players were expected to practice during the weekends for 3-4 hours in the local gymnastic clubs. They were expected to train for about 10-15 hours/week including sessions of aquatic endurance, technical work and resistance training. Control males were selected among the University Teknologi Malaysia (UTM) students, and they were not supposed to follow physical activity programmers. After having been informed about the objectives and the procedures of the research, the participants were expected to follow their informed consent. The study was carried out in conformity with the ethical standards laid down in the Malaysia National Standard and UTM standard according to the experimental ethics code.

BIA measurements

All participants are subjected to be studied at day after a fasting (4 h fast) by the same operator. Body weight was measured to the nearest 0.1 kg using a platform beam scale, and body height was measured to the nearest 0.5 cm. BMI (body mass index) was calculated as: $\frac{Body\ Weight\ (kg)}{height^2(m^2)}$. BIA also was performed by a phase-sensitive device using Tatina BC541 AND Bio-impedance Analyzer BIA450 from the UTM facility. Data for Z, R and PhA at 50 kHz were considered for the present study (dominant and non-dominant sides of the body). Measurements were carried out in standardized conditions (i.e., ambient temperature between 23 and 25 °C, fast >3 h, empty bladder, supine position for at least 10 min before starting the measurement). In addition, after cleaning skin surface, patients were asked to lay with upper and lower limbs slightly abducted, so there was no contact between the extremities and trunk. The measuring electrodes were placed on the anterior surface of the wrists and ankles, and the injecting electrodes were placed on the dorsal surface of the hands and the feet, respectively. For the right body side, the injecting electrodes are always those on the dorsal surface of the right hand and foot, while the measuring electrodes were placed as follows: right and left wrists for right upper limb, right and left ankles for right lower limb. A symmetrical placement of the electrodes was used for left upper or lower limbs. Z, R and PhA were measured injecting a specific value of imperceptible electrical current. This evaluation was conducted in accordance with the segmental approach. Finally, FFM was estimated using the mean value of R for dominant and non-dominant sides and using the predictive equations developed by Sun. Fat mass (FM) was determined by the difference between body weight and FFM.

Bioimpedance Analyzer BIA 450

Bioimpedance testing provides health care practitioners with a non-invasive tool for objectively monitoring body composition - a key indicator of health and vitality. These measurements increase the certainty of an accurate assessment and allow the practitioner to develop and prioritize nutrition and supplement programs and strategies. The Biodynamics BIA 450 Bioimpedance Analyzer provides a direct readout of the impedance of the human body, estimates of mass distribution and body water compartments using electrical tissue conductivity.

RESULT AND DISCUSSION

Active vs. Inactive Phase Angle

The aim of this study was to compare the effects of different training and exercise program on PhA for active and inactive adults (< 35 years old) in Johor Bahru, Malaysia. Although both groups had variety of PhA distribution, the major effects on the examined parameters were measured in the groups. In fact, inactive and active group have average PhA value of 6.69 and 7.1, respectively. Though, the changes of PhA in the active group is more random than the inactive group. This may imply that; the active group participants practice different types of physical activity which has direct effects on the determination of PhA and other variables of BIA measurements (Di Vincenzo et al., 2019). On the other hand, some inactive individuals have higher value of PhA than the active participants, which could be due to their food habit and healthy routine that might increase their PhA values. The regression analysis between both groups indicated that physical activities have positive relationship on

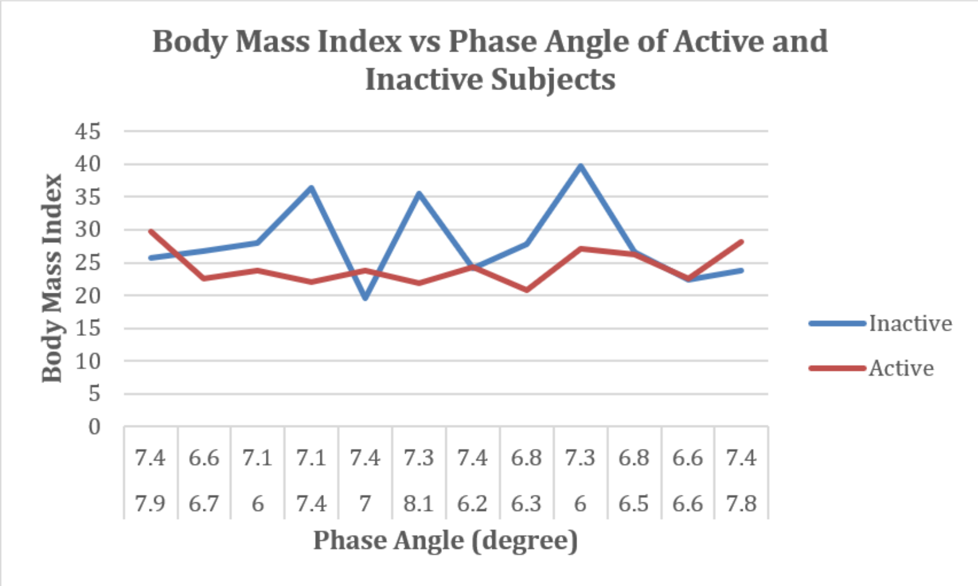

Fig 3. Body Mass Index vs Phase Angle in (Active and Inactive

the increase of PhA values, though the relation is not linear. Moreover, the ANOVA (at 95% CI) analysis indicated that the collected data of the active is larger than the inactive group.

Therefore, the bioimpedance vector analysis of PhA could be useful in clinical and sports fields to study the change in body fluids and nutritional state. It represents the raw bioimpedance parameters (resistance (R) and reactance (Xc)) as a point on the R–Xcgraph in which both length and slope are considered (Hetherington-Rauth et al., 2021; Marini et al., 2020). Recent studies on obese people have taken into consideration PhA and its relationship to different health status measurements, suggesting it as a biomarker to quantify inflammation, which might help in identifying high-risk patients (Campa et al., 2021; Genton et al., 2020). In particular, it has been shown that adult male with a low PhA have high fat mass with high levels of glucose and higher cardiovascular risk factors. On the other hand, in relation to muscle function, improvements in PhA are also associated with increases in muscle strength. In this regard, muscle strength and PhA, indicators of muscle quality, have shown to be more significant than muscle mass in estimating health risk for active and inactive adults.

Moreover, Pearson's coefficient test revealed that active and inactive participant has different degree of relationship with the age of the participants. Figure 1 demonstrates the linear graph of Phase Angle vs. Age of the participants. The correlation analysis produced the value of r as 0.71 and 0.29 respectively for the inactive and active participants. This implies that there is a very strong positive relationship between the age and phase angle values of the participants, in majority of the cases, phase angle is more likely to increase as the age of the participants are higher. This could be due to the fact that within the selected age limit (18-35 years old), the functionality of the body cells increases for healthy people and thereby an increase in the PhA value could be observed as the age of the subjects increases. However, active participants show very week positive relationship between the age of the participants and phase angle. Therefore, for the physically active participants it can be easily implied that the value of phase angle is not strongly dependent on the age of the participants. The value of phase angle most likely varies according to the intensity and types of the physical activities of the participants.

Effects of PhA on Basal Metabolic Rate (BMR) and Fat Mass (FM)

PhA describes the shift between the voltage and the administered current, which is due to the capacitance of cell membranes and tissue interfaces. Thus, it should be influenced by the amount of body cell mass (i.e., the compartment where the largest part of the metabolic processes occurs), alterations in cell membranes and changes in extra-cellular fluids. Actually, PhA is reduced in conditions where an increase of extra-cellular water occurs and are positively corelated with the physical activity status of the participants (Genton et al., 2020). In particular, in agreement with a previous study showing an increase in extra-cellular water in the participants, PhA is low in under nourished participants, suggesting that the alterations of such a variable are specifically related to primary protein-energy malnutrition. We have information while PhA is decreased and so clearly related to the participants without any daily or weekly physical activities (Figure 2). However, considering the evidence available in the result, it could be speculated that PhA reflects changes in the ratio between extra-cellular and intra-cellular water (probably an increase in extra-cellular water), or the relative amount of body cell mass (as a percentage of FFM), or is an index of the severity of malnutrition and/ or physical activities (Di Vincenzo et al., 2019; Martins et al., 2021). However, our results suggest that it was clearly related to the size or the activity of metabolically active tissues. Indeed, it can be useful from a practical point of view if facilities for indirect calorimetry are not available

Effects of PhA on Body Mass Index (BMI)

The importance of BMI and PhA in muscle quantity and strength for health status is well established. Muscle mass and strength have been shown to decrease in inactive participants, and this decline is mediated by body fat as well as BMI. The effects of PhA in the BMI of active and inactive participants are evident from the results. The regression analysis also has proved a positive relationship between the PhA and BMI not only the relationship between physical activity status of the participants but also the neuration level of the participants. However, from the result, it is evident that BMI decreases as the PhA increases. Though, inactive participants have comparative higher value of BMI than the active individuals (Figure 3). Thus, a better understanding of simple markers of skeletal muscle mass and strength in the current sample of active and inactive adult male is relevant since previous studies underlined other consequences in this population. Since PhA is a direct derivative of the raw bioelectrical impedance parameters and given its association with mass and strength, it can be additionally considered as a predictor of skeletal muscle mass and strength, notwithstanding the careful attention that is required in data interpretation (Francisco et al., 2020; Silva et al., 2020). Moreover, PhA reflects cellular integrity, and it facilitates the identification of conditions related to inflammation and accumulation of extracellular fluids, a scenario associated with participants' physical activity status and types, which worsens in people exposed to an increased time of sedentary behaviour.

muscle mass and fat mass (Campa et al., 2021; Genton et al., 2020). Additionally, even if the direct association between mass and strength is currently debated, muscle mass is still one of the factors that contribute to the production of strength. Finally, the study also confirmed the effects of PhA and FM and FFM (fat free mass) of the active and inactive male adults (Figure 4).

CONCLUSION

This study showed that PhA in active group of people are significantly higher than those of inactive adult males. In particular, in this study, PhA was determined from the bioimpedance raw parameters rather than by a gold standard method and indicated that active participants have higher average PhA than the inactive participants. However, the more participants and categorized analysis could be helpful for the identification of risk factors and health status associated with the BIA measurements. We are hoping to conduct a thorough study in a wider population and categorized activities in the future studies. Finally, it can be concluded that it is easy method to monitor the condition of participants in various physical activities and health conditions along with diseases. High value of Phase angle indicates good health of subjects. Individual with low value of phase angle has higher health or injury risks than those with high value of Phase angle. Therefore, PhA is an effective health indicator.

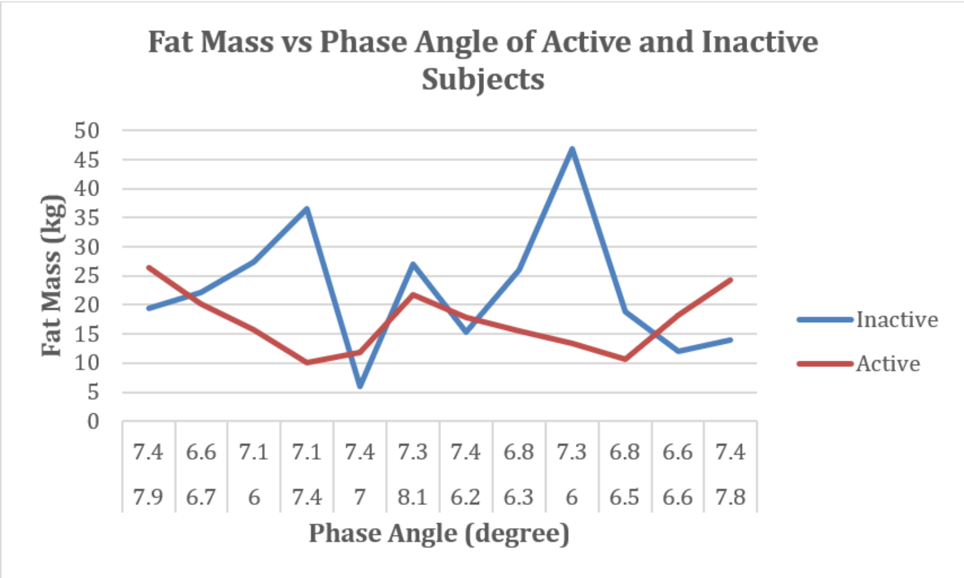

Fig 4. Fat Mass vs Phase Angle in (Active and Inactive).

Effects of PhA on Fat Mass (FM)

Preceding studies have linked PhA with sports performance and competitive level in athletes. In this study, the relationship between PhA and physical activity status was shown, also highlighting how it is inversely correlated with perceived changes in FM among the participants. Furthermore, in healthy adults practicing similar disciplines, higher PhA values have been identified in participants belonging to active males with different physical status. As far as we know, although previous investigations aimed to study the role of PhA as a predictor of muscle strength in people affected by disease or elderly, our study was the first to relate PhA and muscle quantity and strength in active people in Johor Bahru, Malaysia. In this regard, it has been shown that PhA is directly related to the volume of intracellular fluids and fat mass, which are expected to increase in close relationship with muscle tissue. For this reason, a higher PhA may be found in individuals with high

ACKNOWLEDGEMENT

The authors would like to acknowledge the members and facilities provided in the Mechano-Biology Laboratory, Department of Biomedical Engineering and Health Sciences, Faculty of Electrical Engineering, Universiti Teknologi Malaysia.

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