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Original Article

Association between the phase angle and muscle-tendon complex function in Japanese athletes: a comparative study

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Abstract. [Purpose] In this study, we investigated the association between the phase angle and the muscle-tendon complex in Japanese athletes and the effects of aging on this association. [Participants and Methods] The study included 61 adult male high school soccer players. Body composition was evaluated using an analyzer, and grip strength and rebound jump index were measured to evaluate muscle-tendon complex function. Study participants were categorized into two groups, and statistical analyses were performed for intergroup comparison of outcomes and to determine the correlation between the phase angle and muscle-tendon complex function. [Results] We observed significant intergroup differences in the phase angle, total body muscle mass, grip strength, and rebound jump index. Additionally, we observed a significant positive correlation between the phase angle and grip strength in adult soccer players. [Conclusion] Our results showed a correlation between the phase angle and muscle-tendon complex function in mature adult athletes but not in high school athletes. These findings suggest that the phase angle may serve as an indicator of muscle quality and overall physical condition in adult athletes. Further research is warranted to investigate the association between the phase angle and other performance measures to gain a better understanding of soccer players' athletic abilities.

Key words: Phase angle, Muscle-tendon complex, Athletes

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INTRODUCTION

Phase angle (PhA) is a body composition index evaluated using bioelectrical impedance analysis that has garnered attention in recent years[1)]. Phase angle serves as a marker of the nutritional status, disease prognosis, and mortality[2–4)]. The decrease in PhA with age is well established, with age and body mass index being the primary determining factors in children and adolescents versus sex and age in adults[5)]. Previous studies demonstrated a relationship between PhA and performance level in athletes, suggesting its potential as an indicator for evaluating athletes beyond routine clinical care[6–8)]. Although the characteristics of PhA in relation to different sports have been investigated in other countries, no study has focused specifically on Japanese soccer players. Athletes are evaluated using various performance tests; among them, grip strength measurement is well-suited for the noninvasive and convenient assessment of muscle function[9)]. Assessing muscle-tendon complex quality can provide valuable insight into an athletes abilities, often evaluated by measuring the rebound jump (RJ)[10)]. The RJ index is calculated based on measurements of ground contact and dwell times, and it is used to assess the performance of the lower-extremity muscle-tendon complex. This value reflects athletic performance[10, 11)].

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Despite the usefulness of PhA in noninvasively measuring athlete health and indicating muscle quality, evaluating the muscle-tendon complex remains a challenge[12]. Consequently, the relationship between PhA and muscle-tendon complex function in athletes remains unknown. Therefore, we aimed to investigate the relationship between PhA and the muscle-tendon complex in Japanese athletes and examine the effects of aging upon it.

PARTICIPANTS AND METHODS

We sought research collaboration from male soccer teams in the Tochigi Prefecture, Japan, and obtained consent from two teams to participate in the study. This study involved 61 participants: 22 players from the second division of the Kanto adult soccer league in Tochigi Prefecture, and 39 players from high school soccer teams in Tochigi Prefecture. Goalkeepers and individuals who experienced lower-extremity trauma within the past 3 months were excluded. In the categorization of high school soccer in Japan, the hierarchy starts with the national league (Premier League), followed by the district league (Prince League) and the prefectural league. The high school soccer team belongs to the second-division league in Tochigi Prefecture. Both teams engaged in specialized soccer training approximately five times a week.

Consent was obtained from the participants themselves as well as from their family members and instructors before enrollment. This study was approved by the Research Ethics Review Committee of the International University of Health and Welfare (approval number: 21-Io-34-2).

Body composition components such as muscle mass, water content, and PhA were assessed using an InBodyS10 body composition analyzer (InBody, Inc., Seoul, South Korea). During body composition measurements, participants ate meals at least 2 hours prior to the measurements and were instructed to eat after the measurements were completed. No strict instructions were given regarding fluid intake, but participants were instructed to void before the body composition measurement. To evaluate muscle-tendon complex function, grip strength and RJ were measured using a digital grip strength meter (D-TKK5401; Takei Scientific Instruments Co., Niigata, Japan) and a jump mat (S-CADE Co., Tokyo, Japan), respectively. We measured grip strength twice for each hand and used the average of the four measurements as the data point. For the RJ, the participants were instructed to perform five consecutive jumps on a mat with a higher height and shorter ground contact time. The RJ index was measured based on these five jumps. Two trials were conducted, with the maximum value used as the data point.

The participants were divided into two groups: Group A comprised the adult soccer players, while Group Y comprised the high school soccer players. An analysis of covariance was conducted using age as a covariate to compare the outcomes between the two groups. Pearson product-moment correlation coefficients were calculated to determine the relationship between PhA and muscle-tendon complex function. The statistical analyses were performed using the SPSS Statistics for Windows version 27 (IBM Corp., Armonk, NY, USA) with a significance level of 5%.

RESULTS

Three goalkeepers and one participant with lower-limb trauma were excluded, resulting in a final total of 57 participants (21 in Group A, 36 in Group Y). The participants' attributes are summarized in Table 1. The results differed significantly for PhA ($p=0.016$), total body muscle mass ($p<0.016$), grip strength ($p=0.046$), and the RJ index ($p=0.006$) (Tables 1 and 2).

In Group A, we observed a significant positive correlation between PhA and grip strength ($r=0.511$; $p=0.018$), whereas no significant correlation was found between PhA and muscle-tendon complex function in Group Y (Table 3).

DISCUSSION

In the present study, we observed a significant difference in the PhA between Groups A and Y. The mean PhA value for Group Y was 6.4 ± 0.5°, which closely aligns with the findings reported by Hayakawa et al. involving 88 Japanese males

Table 1. Basic information of the two groups of participants

	Group Y n=36	Group A n=21	p-value
Age (years)	16.4 ± 0.6	25.6 ± 3.9	**
Height (cm)	170.4 ± 5.7	172.6 ± 6.1	
Weight (kg)	62.2 ± 5.8	70.1 ± 6.5	**
BMI (kg/m^2)	23.5 ± 1.4	21.4 ± 1.7	**

Group Y: High school soccer players, Group A: Adult soccer players.
Values are presented as the mean ± standard deviation.
Analysis of covariance: *$p<0.05$, **$p<0.01$.
BMI: body mass index.

Table 2. Comparison between Group Y and Group A adjusted for age

	Group Y n=36	Group A n=21	p-value
Phase angle (°)	6.4 ± 0.5	7.2 ± 0.5	*
Total body muscle mass (kg)	50.2 ± 4.3	56.2 ± 4.2	*
Lower limb muscle mass (kg)	17.2 ± 2.0	18.7 ± 1.8	
Grip strength (kg)	35.2 ± 5.2	42.7 ± 6.5	*
RJ index	2.13 ± 0.42	2.41 ± 0.47	**

Group Y: High school soccer players, Group A: Adult soccer players.
Values are presented as the mean ± standard deviation.
Analysis of covariance: *p<0.05, **p<0.01.
RJ: rebound jump.

Table 3. Results of correlation analysis of PhA and muscle-tendon complex for the two groups of participants

	Grip strength	RJ index
Group Y	0.155	−0.114
Group A	0.511*	0.276

Group Y: High school soccer players, Group A: Adult soccer players.
Pearson product-moment correlation coefficient: *p<0.05.
PhA: phase angle; RJ: rebound jump.

aged 18.5 ± 0.5 years with a mean PhA value of 6.5 ± 0.4°[13]. Therefore, we considered the PhA in our study consistent with data from the general population. Previous studies reported that subcutaneous fat tends to decrease at 12–14 years of age in Japanese adolescent boys, followed by an increase after 15 years of age[14]. There is a tendency for muscle cross-sectional area to increase during ages 7–18 years, suggesting developmental changes in body composition components, including muscle tissue, during adolescence[14]. Given that PhA reflects health status and is influenced by developmental processes during adolescence, it can be presumed that the PhA of Group Y, which consisted of adolescents, would be significantly lower than that of Group A, which comprised adults.

In a previous study, differences in muscle mass contributed to variations in grip strength[15]. In our study, significant intergroup differences were observed in grip strength and whole-body muscle mass. Consistent with previous findings[16], no significant increase in lower-limb muscle mass was noted after adolescence; moreover, no significant difference was observed between the two groups in this study. However, despite the lack of change in lower-limb muscle mass, a significant difference was observed in the RJ index, an assessment of lower-limb motor performance. The RJ index plateaus at 16–20 years of age[10]. Notably, elite athletes continue to improve even after 18 years of age, and individual differences become more significant in adulthood, with a tendency for disparities to widen after adolescence[17]. Excellent soccer players who undergo intensive training and competition often exhibit explosive power for a short period and are known to have a high RJ index[17]. Moreover, multiple studies reported that the grip strength differs between elite and lower-level athletes[18]. Therefore, there was a likely difference in the competitive level between the two groups compared here.

The functional measurement results in Table 3 suggest that PhA, which reflects muscle quality, and muscle-tendon complex function, are not correlated in high school athletes. In contrast, mature adult athletes had a high PhA, which correlated with grip strength, a parameter indicating whole-body muscle mass and physical condition. However, PhA was not correlated with the RJ index, indicating tendon function. The findings of this study demonstrated a significant relationship between PhA and muscle-tendon complex function in the mature adult athletes, whereas no such association was observed in the high school athletes. These results suggest that PhA could serve as an informative indicator of muscle quality and overall physical condition, specifically in adult athletes. PhA was a useful indicator for evaluating athletes, although adjustments may be necessary depending on competitive level and age.

This study had a few limitations. First, its sample size was relatively small, which may restrict the generalizability of our findings. A larger sample size would have yielded more robust results. Second, the study lacked a control group of non-athletes or individuals from different sports, limiting its ability to make comprehensive comparisons and draw broader conclusions. Third, the study design was cross-sectional and only provided a snapshot of the data at a specific point in time. A longitudinal design would have allowed for a more in-depth understanding of the relationship between PhA and muscle-tendon complex function. Fourth, potential confounding factors that could influence the observed associations, such as training intensity, training duration, or sports-specific factors, were not accounted for in the analysis. Fifth, the study focused exclusively on male participants and the findings may not be generalizable to female athletes. Sixth, the assessment of muscle-tendon complex function relies on grip strength and RJ measurements, which may not fully capture the complexity

of this system. Including additional objective measures would have enabled a more comprehensive evaluation of the muscle-tendon complex function. These limitations should be considered when interpreting the results of this study and provide opportunities for future research to address these gaps.

Conflicts of interest

The authors declare no conflicts of interest.

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