Concerns Over the Utility of Phase Angle and its Association with Muscle Function

Commentary

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Abstract

Introduction: Phase angle (PhA) derived from bioelectrical impedance analysis (BIA) has been used as an indicator of cellular hydration, muscle function, and nutritional status. Positive relationships between PhA and various measures of muscle function have been reported but it remains unclear whether PhA retains its predictive utility of muscle function, or whether it performs better than fat-free mass (FFM) in the context of muscle function.

Methods: This perspective highlights secondary analyses of data collected during a randomized, double-blind, placebo-controlled trial that examined indices of recovery with different whey protein supplements after muscle-damaging exercise among resistance-trained adults.

Results: Bivariate correlations between phase angle and quadriceps twitch force were positively correlated at baseline, 24-h, and 72-h post-exercise. In linear regression, FFM was shown to account for nearly 44% (partial r = 0.662) of the variance in quadriceps twitch force independent of phase angle at 24-h. A similar pattern emerged at 48-h and 72-h post-exercise

Conclusions: Within this framework, these data demonstrate that: 1) PhA exhibits a weaker correlation to quadriceps twitch force compared to FFM and 2) in the context of muscle function, PhA does not provide additional information beyond that of FFM alone. Investigators should consider adjusting for FFM when evaluating the relationship between PhA and muscle function outcomes.

Key Words: bioelectrical impedance analysis, strength athletes, body composition, recovery

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Commentary

Measurement of body composition is a relevant practice given the implications for health and physical performance. Bioelectrical impedance analysis (BIA) offers practical utility to measure body composition by offering portability, simplicity, and agreement with reference methods (e.g., dual-energy X-ray absorptiometry) in body composition evaluations[1]. Phase angle (PhA), a raw parameter derived from BIA, is expressed as the BIA-derived ratio of reactance (capacitive properties for an electric current) and resistance (resistive properties for an electric current). Prior work has used PhA as an indicator characterizing cellular membrane integrity, intracellular and extracellular fluids[2]. Indeed, multiple reports suggest PhA can serve as a marker of malnutrition[2] and muscle quality[3] in varying populations.

Phase angle dimensions typically range from 1° to 12°[4], with a higher value being positively associated with muscle cell mass[5] and muscle quality[6], both of which are significant determinants of overall muscle tissue functionality[7]. For example, prior work has shown greater PhA is linked with muscle strength and physical function[8,9], countermovement jump performance among athletes[10] as well as strength/power in active individuals[11]. From a practical perspective, PhA is thought to reflect cellular membrane integrity and function[8], both of which may be relevant factors in neuromuscular performance. Though PhA might serve as a useful method to evaluate muscle function, the relationship between PhA and neuromuscular properties remains incompletely understood. To address this, we performed secondary analyses on data collected during our randomized, double-blind, placebo-controlled trial, designed to assess whether whey protein type differentially affects signs and symptoms of exercise-induced muscle damage (EIMD) in resistance trained individuals[12]. Healthy individuals of both sexes (aged 18-40 years) who had resistance-trained for ≥3 months with ≥3 days/week of resistance training, were free from known metabolic, cardiovascular, and musculoskeletal diseases, and were not allergic to dairy, were considered suitable for this experiment. Furthermore, all male and female participants were required to produce a barbell back squat with an estimated one repetition maximum of ≥1.5 and ≥1.25 times their body mass for male and female subjects, respectively (obtained on visit 1). A multi frequency segmental body composition instrument (Tanita MC-780U, Tanita Corp., Tokyo, Japan) was used to measure body mass, body fat percentage, fat free mass, and PhA. Prior to this, hydration state was measured via urine specific gravity using a handheld refractometer (Pen S.G., Atago, Tokyo, Japan), where urine specific gravity <1.020 indicated euhydration. If subjects arrived at the laboratory with urine specific gravity above 1.020, they were provided with 300 ml of water to consume immediately. Herein, we explored the relationship between PhA and quadriceps twitch force via magnetic stimulation – a technique that superimposes an electrical impulse to maximally induce muscle contraction.

Table 1 depicts bivariate correlations between baseline PhA (taken before exercise) and quadriceps twitch force. These data reveal statistically significant positive correlations at baseline, 24-h, and 72-h post-EIMD. Since PhA is associated with cell membrane integrity[8], it is reasonable to suggest that a larger PhA may reflect an enhanced ability to transmit evoked action potentials across myocellular membranes[13] – such a scenario would enhance potentiated twitch force. These data are consistent with other work[2,3,8,9], suggesting PhA may be a relevant biomarker in the context of muscle quality and function. However, it remains unclear whether PhA retains its predictive utility of muscle function, and if it performs better than fat-free mass (FFM), which is also a predictor of quadriceps twitch force. This is especially relevant since skeletal muscle mass is a substantial reservoir for fluids and electrolytes both of which are relevant in the propagation of a neuromuscular signal[4].

Table 1. Simple correlation matrix of baseline phase angle (PhA) and fat free mass (FFM) separately with quadriceps twitch force at baseline, 24, 48, and 72 hours after exercise-induced muscle damage (EIMD).

	Baseline	24 h post-EIMD	48 h post-EIMD	72 h post-EIMD
PhA	0.369*	0.326*	0.300	0.320*
FFM	0.633*	0.705*	0.664*	0.622*

*denotes statistical significance at p-value ≤ 0.05.

Based on Table 2, inclusion of PhA and FFM in regression modeling shows that nearly 44% of the variance (partial r = 0.662) in the quadriceps twitch force at 24-h may be attributed to FFM. A similar pattern emerges at 48-h and 72-h post-EIMD, which are independent of PhA. Other measures of muscle function and performance assessed in our previous work[12], such as maximal isometric voluntary contraction and barbell back squat velocity, did not exhibit a relationship with PhA (data not shown). Countermovement jump, on the other hand, did correlate with PhA but statistical significance was not reached when adjusting for FFM (data not shown).

The correlation coefficients suggest that individuals with larger PhA's exert greater knee extensor muscle force due to magnetically evoked stimuli. Previous studies testing the plantar flexors[13] and knee extensors[14] aligns with our unadjusted findings, although participants from those studies were older and less resistance-trained individuals. Of note, these works[13,14] and others[15,16] did not determine if the relationship between PhA and muscle function persisted independent of FFM. Our data suggest FFM is primarily influencing the relationship between PhA and muscle function. Likewise, Langer and colleagues showed in male Army cadets that PhA via BIA explained just 3% of the muscle strength variation (handgrip strength), whereas lean soft tissue explained 39%[17]. Within our work, PhA explained 0.2%, 0.08%, and 0.6% of the variance in quadriceps twitch force at 24, 48, and 72 hours post-EIMD, respectively. Additionally, Fukuoka and colleagues concluded that bioimpedance-derived lean soft tissue, not PhA or fat mass is the most important predictor of muscle strength and power (Wingate test and one-rep maximum bench press and squat) in resistance-trained individuals[9], which corroborates with our work and others[17]. On the other hand, Hetherington-Rauth and colleagues have suggested that PhA provides additional information on muscle performance (handgrip strength and countermovement jump) beyond what can be explained via FFM alone[18]. It is possible, although uncertain, that such discrepancy in PhA utility can be explained due to the fact that differing methods, BIA[12] and dual-energy x-ray absorptiometry[18] were used to measure FFM in prior reports. Additionally, bone mineral content was included in our FFM measure[12] while it was subtracted in the previously mentioned work[18]. Lastly, participants in our study[12] were resistance-trained athletes with an average FFM of 60.0 kg, not track & field and sports-based athletes with an average lean soft tissue of 51.3 kg[18], which may explain the PhA discrepancy between the present work and Hetherington-Rauth and colleagues.

Table 2. Regression modeling of quadriceps twitch force at baseline, 24, 48, and 72 hours after EIMD adjusted for FFM.

		Model R	R^2	partial *r*	*p*-value
Baseline					
Adjusted for FFM	PhA	0.643	0.414	0.146	0.382
	FFM			0.567*	< 0.001
24 h post-EIMD					
Adjusted for FFM	PhA	0.705	0.498	0.046	0.786
	FFM			0.662*	< 0.001
48 h post-EIMD					
Adjusted for FFM	PhA	0.664	0.441	0.029	0.863
	FFM			0.622*	< 0.001
72 h post-EIMD					
Adjusted for FFM	PhA	0.625	0.391	0.081	0.630
	FFM			0.567*	< 0.001

EIMD: exercise-induced muscle damage. FFM: Fat Free Mass. PhA: Phase Angle. *denotes statistical significance at p-value ≤ 0.05.

Based on the current work, our data suggest FFM is primarily influencing the relationship between PhA and muscle function. Due to its simplicity, non-invasiveness, and validity, PhA will likely continue to be measured in future research. Ensuing research should examine and clarify the specific role of PhA in strength-based and endurance-based athletes. Regardless, investigators are urged to adjust for FFM when evaluating the relationship between PhA and varying muscle performance outcomes.

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