Title: Phase angle as an indicator of health and fitness in patients entering an exercise referral scheme

Authors: Steven Mann[1,2], Matthew Wade[1], James Fisher[3], Jürgen Giessing[4], Paulo Gentil[5], James Steele[1,3]

Affiliations: [1]ukactive Research Institute, [2]Places for People Leisure, [3]Solent University, [4]University of Koblenz-Landau, [5]Federal University of Goias,

Corresponding author email: jamessteele@ukactive.org.uk

Corresponding author address:
James Steele
26-28 Bedford Row,
London,
WC1R 4HE

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The loss of function as we age may be related to changes at the cellular level[1]. Recently attention has been given to measurement of the phase angle (PhA); a non-invasive simple measure using bioelectrical impedance analysis (BIA). Indeed, PhA is considered a valuable indicator of cellular health and, as it is derived purely from electrical properties of the tissue it avoids typical concerns associated with BIA using prediction equations. PhA is calculated from the arctangent of the ratio between the resistance and reactance from BIA and a number of studies have evidenced its associations with age and sex[2], lean body mass[3], and strength[4]. Indeed, PhA has even been shown to be predictive of mortality risk[4].

Physical fitness is important for health and longevity, and it has been argued that measurements should be considered routinely in clinical practice[5,6]. Yet, with limited time many General Practitioners (GPs) do not engage in discussions around physical activity or fitness[7] let alone have time for their measurement. However, BIA is a quick and simple measure and, if PhA is predictive of such outcomes, may offer a valuable alternative for GPs and other clinical practitioners. Despite various studies in other specific clinical populations[4,8,9] there is little research considering the typical person at elevated risk of cardiometabolic disease or type 2 diabetes who might present to their GP and be referred for exercise. As such, the aim of this study was to examine the predictive value of PhA with respect to these measures in a sample of exercise referral patients.

This study was a cross-sectional analysis of data collected in a wider trial of exercise referral schemes from 146 patients who were overweight and/or obese (BMI 25-35), and/or at increased risk of type 2 diabetes as determined by their GP. Relationships between PhA and a range of common health measures used as risk factors including BMI, systolic blood pressure (SBP), diastolic blood pressure (DBP), and body fat were examined, in addition to lean body mass, muscular strength, and cardiorespiratory fitness. Pearson's or Spearman's correlations were performed dependent upon distribution and 95% confidence intervals calculated. Hierarchical multiple linear regression was also performed using examining the predictive capacity of PhA as the independent variable upon dependent variables and adjusting for inclusion of both age and sex. An $\alpha$ of 0.05 was accepted as the threshold for statistical significance.

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PhA was found to be significantly correlated with age ($r$ = -0.392; -0.240 to -0.525), body mass ($r$ = 0.205; 0.038 to 0.361), lean mass ($r$ = 0.353; 0.197 to 0.492), and muscular strength ($r$ = 0.368; 0.186 to 0.525). Model 1 considering PhA as an independent variable alone was significantly predictive of body fat, lean body mass, and muscular strength. However, variance explained for these was significantly increased when age and sex were included (Model 3). The final models of PhA, age, and sex to predict body fat ($R^2$ = 0.477, $F_{(3,133)}$ = 40.376, $p$ < 0.001, adj. $R^2$ = 0.465), lean body mass ($R^2$ = 0.458, $F_{(3,133)}$ = 37.391, $p$ < 0.001, adj. $R^2$ = 0.445), and muscular strength ($R^2$ = 0.278, $F_{(3,98)}$ = 12.595, $p$ < 0.001, adj. $R^2$ = 0.256) were all statistically significant. Model coefficients for body fat, lean body mass, and muscular strength are shown in table 1.

Similarly to previous studies, our findings show PhA appears to be primarily linked to elements of body composition and muscular health and fitness including body fat, lean body mass, and muscular strength, whereas it was not linked to other traditional risk factors such as BMI, SBP, or DBP, or fitness measures such as $VO_{2max}$. Considering its ease of administration, PhA might be considered as a simple indicator of cellular and overall muscular health which could be employed by GPs in screening patients.

Identification of low PhA might be a useful clinical marker to aid in prescription of exercise interventions for patients. As PhA appears to most strongly predict muscular health and fitness it might be used to indicate patients who might benefit most from resistance training-based interventions. Despite GPs rarely prescribing physical activity of any kind, resistance training is an approach which receives comparatively less emphasis even compared to other modalities. Simple approaches to resistance training using low volume and frequency in line with current guidelines are effective in improving PhA[10]. Future work should consider larger samples and examine the effectiveness of different exercise referral schemes upon PhA to identify if this clinical marker can also be used to identify changes as a result of such interventions.

## Conflict of interest statement

There are no known conflicts of interest.

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Table 1. Model coefficients for body fat, lean body mass, and muscular strength.

| | Model 1 | | Model 2 | | Model 3 | |
|---|---|---|---|---|---|---|
| | B | β | B | β | B | β |
| Body Fat | | | | | | |
| (Constant) | 51.580** | | 58.165** | | 52.127** | |
| PhA | -2.193* | -0.187 | -2.649* | -0.226 | 0.337 | 0.029 |
| Age | | | -0.076 | -0.099 | 0.111* | 0.145 |
| Sex | | | | | -15.994** | -0.714 |
| Lean Body Mass | | | | | | |
| (Constant) | 21.530* | | 20.281 | | 26.783* | |
| PhA | 5.351** | 0.366 | 5.438** | 0.372 | 2.223* | 0.152 |
| Age | | | 0.014 | 0.015 | -0.188* | -0.196 |
| Sex | | | | | 17.225** | 1.934 |
| Muscular Strength | | | | | | |
| (Constant) | -6.092 | | -5.339 | | -0.324 | |
| PhA | 6.009** | 0.337 | 5.956* | 0.333 | 3.103 | 0.174 |
| Age | | | -0.008 | -0.007 | -0.150 | -0.129 |
| Sex | | | | | 14.175** | 0.434 |

Note: *$p \leq 0.05$; **$p \leq 0.001$

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