

# Postural Control is Associated with Functionality and Cell Health in Elderly.

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## Research article

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# Abstract

Background: Alterations in cellular health and postural control occur with aging and contribute to the increased risk of falls. The aim of this study was to analyse the relationship between static balance in relation to functionality and cell health. Methods: We evaluated 21 elderly people of both sexes, aged  $\geq 60$  years (11 men:  $77 \pm 9$  years; 10 women:  $74 \pm 10$  years). The ability and quality of maintaining balance in standing posture measured by the movement of the pressure center (CoP) for seven positions: feet separated open and closed eyes (FSEO, FSEC), feet together open and closed eyes (FTEO, FTEC), semi-tandem open and closed eyes (STEO, STEC), and one-legged-support (OLS). Cellular health was measured by means of electrical bioimpedance (BIA) and functionality through the Timed Up and Go Test (TUG) and Short Physical Performance Battery (SPPB). Results: In the analysis of the mediolateral velocity of the positions FSEO, FSEC, FTEC, and STEO on the platform, an inverse correlation between balance and bioelectrical impedance variables were verified for all models, with a coefficient of explanation ( $r^2$ ) varying between 20% (resistance in FSEO position) and 74% (reactance in STEO position, Model 3). Inverse and significant correlations between reactance and phase angle in the OLS position was verified, in all adjustment models, with coefficient of explanation varying between 62% (phase angle, OLS area, Model 1) and 91% (same variables, Model 3). In the analysis of mediolateral velocity for the STEC position, positive correlation with TUG and an inverse correlation with reactance, resistance, phase angle were observed, with coefficient of explanation varying between 21% (resistance, Model 1) and 67% (reactance, Model 3). Conclusions: The postural control is linearly related to bioimpedance parameters and functionality in elderly. The assessment of balance can provide important information on the health condition of the elderly, and furnishes useful insights for prevention and treatment strategies.

## Background

During the aging process, physical abilities decrease concomitantly to changes in the postural control mechanism (1, 2). Lower limb weakness and deterioration of balance are associated with an increased risk of falls, functional limitations, hospitalizations, and increased mortality (3–6). Studies have also observed a positive correlation between muscle strength and maintaining balance in an upright posture (7). In addition, a relation between static body balance and risk of falls has been reported (8–10).

The static body balance can be evaluated with measures that characterize the displacements with the behavior of a point corresponding to the projection of the pressure center (CoP). Traditional measures of the CoP displacement during the static and erect position quantify the movement of the CoP trajectory (11).

Other markers are used to identify deleterious effects over impaired balance as a function of aging. Among them, bioimpedance (BIA) is being used with increasing frequency, because of its ability to indicate cell health, body composition and distribution of intra- and extracellular fluids, low cost, little complexity in the measurement and portability. Impedance consists of two variables: resistance (R), that determines the state of hydration of the tissue, and reactance ( $X_c$ ), that determines the amount of energy

that can be accumulated in the tissue (12). The phase angle (PhA), which is a relation between Xc and R, has been interpreted as an indicator of cell membrane integrity, in addition to associating muscle mass, strength and body fat (13–15). PhA decreases with the aging process, especially due to the reduction of Xc, and is related to the reduction of the proportion of total body water (12) and of the relationship between extracellular and intracellular water (16, 17). Still, positive correlations between phase angle, mass and muscle strength were observed in elderly people, which makes this marker a probable identifier of the risk of sarcopenia in the studied population (18). For these reasons, PhA is considered a health indicator, especially in populations with chronic diseases (19). It is not yet known whether associations between phase angle and balance in different positions are present in the elderly. In this context, assessing the postural balance becomes relevant to the design specific prevention and treatment strategies in the elderly.

The aim of this study was to evaluate the relationship between static balance, in seven positions, in relation to functionality and health cellular. The authors hypothesize that the better the postural control of the elderly, measured in each of the seven positions, the better the responses of bioimpedance parameters and cellular integrity.

## **Methods**

### **Participants**

The elderly population from the city of Presidente Prudente, SP, Brazil, was invited to participate in a major study (24-month cohort) at the São Paulo State University. The study was advertised by the local media, and the individuals voluntarily presented themselves at the institution. All participants completed health history questionnaires and met the following inclusion criteria: individuals of 60 years or older and have lived in Presidente Prudente, SP, Brazil, for at least two years. The exclusion criteria were: inability to walk, bedridden, having a pacemaker, and institutionalized elderly and incomplete personal data in the database. Twenty-one elderly (women=11, men=10) agreed to participate in the proposed evaluations and inclusion in the study. After being informed about the study objectives and data collection procedures, participants signed the consent form. All protocols were reviewed and approved by the Research Ethics Committee of the São Paulo State University and registered in ICTRP/OMS (Clinical trial number - RBR-2624R4).

### **Study design**

Data were collected in October 2018. All study participants were evaluated for 1 week. The evaluations were carried out in 2 consecutive days. On the first day, the anthropometric measurements and bioelectrical impedance (BIA). On the following day, the balance evaluation and function tests were performed. All participants were evaluated by the same evaluator to reduce bias.

### **Measurements**

## Anthropometry and body composition data

Anthropometry data (weight, in kg, and height, in m) were measured according to procedures described by Lohman et al. (1988), and body mass index were estimated ( $BMI = W.H^{-2}$ ). Measurements were performed with the patient in orthostatic position in a Balmak model BK-200FA class III balances and stadiometer. The participants remained barefoot, wearing light clothing and standing at the base of the stadiometer, positioning themselves with their backs to the machine, touching their shoulder blades, buttocks and heels to the equipment's vertical support.

## Body composition

A spectral bioelectrical impedance (BIA Analyzer, Nutritional Solutions, Harrisville, MI, USA) device was used to determine (R) and (Xc) and subsequently, the phase angle (PhA) was calculated by arc-tangent  $(Xc/R) \times 180^\circ / \pi R$ . Participants were instructed to urinate before the measures, refrain from ingesting food or drink in the previous 4 h, avoid strenuous physical exercise for at least 24 h, refrain from the consumption of alcoholic or caffeinated beverages for at least 48 h and avoid the use of diuretics during the seven days preceding collection. All participants were measured in dorsal decubitus, lying on a stretcher isolated from electric conductors, in the supinated position, with the legs abducted at a 45° angle. After cleaning the skin with alcohol, four electrodes were placed on the surface of the hand and the right foot.

## Standing Balance

### CoP movement

The postural balance assessment was performed on the AMTI force platform (FP) (model OR6-7,USA), with data acquisition performed at a frequency of 100 Hz. Participants remained in the center of the FP with arms relaxed at the side of the trunk, barefoot, in a static posture, in seven experimental conditions: (1) feet separated eyes open (FSEO); (2) feet separated eyes closed (FSEC); (3) feet together with eyes open (FTEO) (4) feet together eyes closed (FTEC) (5) semi-tandem eyes open (STEO) (6), semi-tandem eyes closed (STEC) (7), one-legged support (OLS). For each task, three tests were performed for 30 seconds, for positions 1 to 4, and 15 seconds for positions 5 to 7, with a rest period of 30 seconds between each test (22,23). During testing with eyes open, the participant would look at a target placed on a wall at eye level 2 m away. To prevent falls during testing, an investigator stood close to the volunteers during all tasks. All participants were familiar with the test procedures, with prior participation in previous simulations. After obtaining the data, a second-order low-pass filter of 10 Hz was used to obtain the variables through routine procedures developed in MATLAB 7.5 software (MATLAB 2007, MathWorks Inc., USA), used to determine the center of pressure. All center of pressure values for all seven experimental conditions are inversely proportional to the optimal equilibrium conditions, lower values of center of pressure indicate better equilibrium patterns.

## **Functional Capacity**

### **Short Physical Performance Battery**

For the mobility test, the motor test battery of Guralnik et al. (1994) was applied, which consisted of three subsequent motor tests: balance test, walk test, and sit-and-stand test. The scores for each test range from 0 to 4 points. Elderly patients with low physical performance scored lower than 6 points on the sum total of the three tests (24).

### **Timed Up-and-Go test**

For the Timed Up-and-Go test (TUG), the time in seconds required for the participants to “rise from a standard arm chair, walk at their typical or normal pace to a line on the floor 3 meters away, turn, return, and sit down again” were registered. (25) Those who completed the TUG tasks in more than 14 s also showed lower scores on the Berg Balance Scale.

### **Statistical Analysis**

A statistical package (SPSS version 22.0, SPSS® Inc., USA) was used for data analysis. Normal distribution of the data was confirmed using the Shapiro-Wilk test. Initially, bivariate correlation analysis was performed. In order to ensure that the results of balance are not influenced, first, by age, and in a second analysis, by differences between the gender and body weight, the independent variables that presented statistical correlation with the balance variables (significance less than 5%) were inserted in three different models of multiple regression analysis: unadjusted model (model 1), adjusted for age (model 2); and adjusted for age, BMI and gender (model 3) model. The significance level was set at  $p < 0.05$ . A similar analysis was performed for mediolateral velocity, for the area analysis, and for the mediolateral velocity in the STEC position.

## **Results**

The characteristics of elderly outpatients are presented in Table 1. Overall, 14.3% and 19.0% of the sample were classified as overweight and obese, respectively, on the basis of BMI and cutoffs.

Table 1  
General characteristics of subjects.

<b>General Characteristics</b>	<b>Whole Sample (N = 21)</b>	<b>Female (N = 11)</b>	<b>Male (N = 10)</b>
Age (y)*	75.6 ± 9.4	74.2 ± 9.6	77.3 ± 9.5
Height (cm)*	159.4 ± 10.5	154.0 ± 11.0	165.4 ± 6.0
Weight (kg)*	66.3 ± 12.3	60.8 ± 12.2	72.5 ± 9.7
Body mass index (kg/m <sup>2</sup> )	26.1 ± 4.5	25.8 ± 5.7	26.4 ± 2.9
<b>Bioelectrical impedance</b>			
Resistance (ohm)*	585.0 ± 86.2	628.9 ± 95.0	536.7 ± 39.4
Reactance (ohm)*	40.4 ± 7.9	43.3 ± 8.2	37.2 ± 6.7
Phase angle (°)	4.0 ± 0.7	4.0 ± 0.7	4.0 ± 0.6
<b>Fall of Felling</b>			
FES-I- BRASIL (score)	29.1 ± 9.9	29.0 ± 9.5	29.2 ± 10.9
<b>Functional tests</b>			
SPPB (score)*	8.8 ± 2.4	8.5 ± 2.5	9.6 ± 2.2
TUG (seconds)	10.5 ± 4.9	11.2 ± 6.3	9.6 ± 2.2
Notes: FES-I- BRASIL = Falls Efficacy Scale International; SPPB = Short Physical Performance Battery; TUG = Timed Up and Go Test. * p < 0.05 between genders			

In the analysis of the mediolateral velocity of the positions (FSEO, FSEC, FTEC and STOE) on the platform, an inverse correlation between balance and bioelectrical impedance variables (resistance and, especially, reactance) was found, demonstrating the close relationship between cellular health and balance (Table 2), regardless of age, BMI and sex. When the area analysis was performed (Table 3), the inverse correlation between resistance, reactance) and balance in the OLS position was verified, in all adjustment models (reactance,  $p < 0.005$ ; phase angle:  $p < 0.05$ ). In addition, there was an inverse correlation between TUG and STEC (model 2, adjusted for age only;  $p = 0.04$ ) and a positive correlation between SPPB and FTEO (model 2, adjusted for age, and model 3, adjusted for age, BMI and sex;  $p < 0.005$ ). In the analysis of the mediolateral velocity for the STEC position (Table 4) a negative relation between reactance, resistance and phase angle ( $p < 0.05$ ) was revealed, while the relation with TUG was positive ( $p < 0.05$ ).

Table 2

Relation between bioimpedance variables and center of pressure movement in medio-lateral direction in different standing positions with eyes open and closed.

Variables	$\beta$ (IC 95%)	$r^2$	Part. Corr.	p- $\beta$	p-model
<b>FSEO vel_ml</b>					
<b>Reactance</b>					
- Model 1	-0.04 (-0.06;-0.01)	0.38	-0.62	0.003	0.003
- Model 2	-0.05 (-0.08;-0.02)	0.43	-0.62	0.006	0.004
- Model 3	-0.06 (-0.10;-0.02)	0.53	-0.67	0.011	0.002
<b>Resistance</b>					
- Model 1	-0.003 (-0.005;-0.000)	0.20	-0.45	0.04	0.04
- Model 2	-0.002 (-0.005;-0.000)	0.27	-0.45	0.06	0.04
- Model 3	-0.004 (-0.008;-0.001)	0.39	-0.52	0.08	0.02
<b>FSEC vel_ml</b>					
<b>Reactance</b>					
- Model 1	-0.04 (-0.07;-0.01)	0.31	-0.55	0.009	0.009
- Model 2	-0.06 (-0.11;-0.02)	0.38	-0.59	0.01	0.006
- Model 3	-0.06 (-0.12;-0.01)	0.39	-0.55	0.08	0.01
<b>FTEC vel_ml</b>					
<b>Reactance</b>					
- Model 1	-0.05 (-0.09;-0.01)	0.32	-0.56	0.009	0.009
- Model 2	-0.07 (-0.13;-0.01)	0.35	-0.53	0.02	0.02
- Model 3	-0.05 (-0.14;-0.004)	0.36	-0.50	0.11	0.04
<b>STEO vel_ml</b>					
<b>Reactance</b>					
- Model 1	-0.07 (-0.09;-0.04)	0.64	-0.80	0.000	0.000
- Model 2	-0.04 (-0.08;-0.01)	0.70	-0.56	0.000	0.01
- Model 3	-0.05 (-0.09;-0.01)	0.74	-0.57	0.000	0.01
Notes: Model 1: no adjustment; Model 2: model 1 + age; Model 3: model 2 + gender and body mass index; vel_ml = velocity mediolateral; FSEO = feet separated eyes open; FSEC = feet separated eyes closed; FTEC = feet together eyes closed; STEO = semi-tandem eyes open.					

Table 3

Relation between functional variables and center of pressure movement in area in different standing positions with eyes open and closed.

Variables	$\beta$ (IC 95%)	$r^2$	Part. Corr.	p- $\beta$	p-model
<b>FTEO area</b>					
<b>SPPB</b>					
- Model 1	-0.15 (-0.67; 0.36)	0.02	-0.15	0.53	0.53
- Model 2	0.32 (-0.12; 0.77)	0.53	0.37	0.003	0.14
- Model 3	0.40 (0.006; 0.81)	0.73	0.52	0.001	0.04
<b>STEC area</b>					
<b>TUG</b>					
- Model 1	-0.22 (-0.85; -0.40)	0.03	-0.18	0.45	0.45
- Model 2	-0.60 (-1.21; 0.01)	0.35	-0.47	0.04	0.05
- Model 3	-0.68 (-1.35; -0.01)	0.42	-0.52	0.11	0.04
<b>OLS area</b>					
<b>Reactance</b>					
- Model 1	-0.64 (-0.86; -0.42)	0.83	-0.91	0.000	0.000
- Model 2	-0.53 (-0.75; -0.30)	0.90	-0.89	0.000	0.001
- Model 3	-0.53 (-0.93; -0.14)	0.90	-0.80	0.005	0.01
<b>OLS area</b>					
<b>Phase angle</b>					
- Model 1	-6.08(-9.61; -2.55)	0.62	-0.80	0.004	0.004
- Model 2	-4.88(-11.18; 1.40)	0.64	-0.53	0.016	0.111
- Model 3	-6.46(-10.54; -2.39)	0.91	-0.85	0.002	0.0008
Notes: Model 1: no adjustment; Model 2: Model 1 + age; Model 3: Model 2 + gender and body mass index; SPPB = Short Physical Performance Battery; TUG = Timed Up and Go Test; FTEO = feet together and eyes open; STEC = semi-tandem eyes closed; OLS = one-legged-support.					

Table 4

Relation between independent variables and center of pressure movement in medio-lateral direction in semi-tandem position with eyes closed.

Variables	$\beta$ (IC 95%)	$r^2$	Part. Corr.	p- $\beta$	p-model
<b>STEC vel_ml</b>					
<b>Reactance</b>					
- Model 1	-0.10 (-0.14;-0.06)	0.65	-0.81	0.000	0.000
- Model 2	-0.10 (-0.16;-0.04)	0.66	-0.67	0.000	0.002
- Model 3	-0.11 (-0.18;-0.04)	0.67	-0.67	0.002	0.004
<b>Resistance</b>					
- Model 1	-0.007 (-0.01; 0.00)	0.21	-0.46	0.04	0.04
- Model 2	-0.006 (-0.01; 0.00)	0.52	-0.48	0.003	0.04
- Model 3	-0.008 (-0.01; 0.00)	0.55	-0.50	0.01	0.04
<b>Phase angle</b>					
- Model 1	-1.16 (-1.79; -0.54)	0.48	-0.70	0.001	0.001
- Model 2	-0.99 (-2.20; 0.20)	0.48	-0.40	0.005	0.098
- Model 3	-1.20 (-2.48; 0.08)	0.53	-0.47	0.022	0.064
<b>TUG</b>					
- Model 1	0.26 (0.13; 0.39)	0.53	0.73	0.001	0.001
- Model 2	0.20 (0.06; 0.34)	0.62	0.62	0.001	0.007
- Model 3	0.21 (0.05; 0.37)	0.65	0.63	0.006	0.011
Notes: Model 1: no adjustment; Model 2: Model 1 + age; Model 3: Model 2 + gender and body mass index; STEC = semi-tandem eyes closed; vel/ml = velocity mediolateral; TUG = Timed Up and Go Test.					

## Discussion

The main results of the present study were on postural control, measured by the variables of the displacement area of the pressure center (A/CoP) and the average oscillation speed in the mediolateral direction (vel /ml) in different conditions on the platform, if correlated in order of relevance with: 1) reactance; 2) phase angle and 3) measures of functionality. Our initial hypothesis was confirmed that the better the postural control of the elderly, the better the responses of the parameters of bioimpedance and cell integrity would be, in addition to the functional response.

In the analysis of the mediolateral velocity of the positions FSEO, FSEC, FTEC, and STEO on the platform, an inverse correlation between balance and bioelectrical impedance variables were verified for all models, with a coefficient of explanation ( $r^2$ ) varying between 20% (resistance in FSEO position) and 74% (reactance in STEO position, Model 3). Inverse and significant correlations between reactance and phase angle in the OLS position was verified, in all adjustment models, with coefficient of explanation varying between 62% (phase angle, OLS area, Model 1) and 91% (same variables, Model 3). In the analysis of mediolateral velocity for the STEO position, positive correlation with TUG and an inverse correlation with reactance, resistance, phase angle were observed, with coefficient of explanation varying between 21% (resistance, Model 1) and 67% (reactance, Model 3)

In the analysis of the variable mediolateral velocity in the positions (FSEO, FSEC, FTEC, and STEO) the inverse correlation between balance and bioelectrical impedance variables, especially the reactance. The close relationship between cellular health and balance in aging, can be predictive of future falls in postural conditions. Our results also indicate that there is a relation between risk of falls and measures of the center of pressure (CoP) and that these measures can be an important tool to identify the risk of falls in the elderly (26–28). Although all CoP parameters of different equilibrium conditions can predict risk for subsequent falls, the various indicators of lateral posture control, such as the CoP mediolateral velocity, have been described as the main one (26). Liu et al. (2018) demonstrated that velocity measurements were the more sensitive measures of differences in balance control and that they increase with age and change in tests with changes in balance control (11). Regarding the findings of the area variable, it was verified that the greater the area, the worse the cellular health condition, which again suggests the presence of a causal relationship between cellular health and balance.

This result is relevant considering the losses in postural control as well as reductions in strength and muscle mass generally detected in the elderly. This is the first study that correlated postural control and bioelectrical variables (indicative of cellular health). Therefore, the negative relation observed, in our sample has not been detected before. However, bioelectrical impedance analysis, and phase angle in particular, have been widely used in the elderly, showing significant relations with nutritional and health status. (14–15)

The inverse correlation found between the TUG and the STEC position demonstrated that the elderly who are in a worse functional condition have greater difficulty to remain in the STEC position. The literature points out the importance of evaluations in the condition of closed eyes since it seems to reflect better results. In a recent review study, the researchers concluded that values of CoP measurements are higher for the closed-eye condition in the elderly group, which corroborates with the findings assessed in the closed-eyed positions in our study (11). It is important to emphasize that the present study analyzed the static postural control, cellular integrity parameters and functional capacity, showing a correlation between them.

The assessment of balance can provide important information on the health condition of the elderly, and furnishes useful insights for prevention and treatment strategies. As the main limitation of the study, the

sample (n = 21) compromises the sampling power, and consequently, the statistical power. On the other hand, the fact that in a small sample such significant correlations were found, increases the chances of results with stronger correlations and for other variables. Likewise, a larger sample allows assessing such correlations according to groups according to clinical condition (obese, sarcopenics) and sex. However, with the results obtained, we can propose the use of the bioelectrical impedance methodology, more precisely of the reactance and phase angle parameters, as proxy variables (substitutes) to the balance variables in force platforms.

## Conclusions

In conclusion, postural control is linearly related to the parameters of bioimpedance and functionality in the elderly. Our results suggest that cell integrity, as measured by the BIA, and functional tests of mobility and dynamic balance can predict postural control in elderly people.

## Abbreviations

A/CoP

area of the pressure center, vel\_ml:velocity mediolateral, FSEO:feet separated eyes open, FSEC:feet separated eyes closed, FTEC:feet together eyes closed, STEO:semi-tandem eyes open, FTEO:feet together and eyes open, STEC:semi-tandem eyes closed, OLS:one-legged-support.

## Declarations

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### Authors' contributions

GNB and BSAS, contributed to conception and design of the study. GNB, IAM, and BSAS implemented the measurements, analysis and interpretation of the data. VRS, EM and LAG made substantial contributions to the acquisition of the data and revising the work. All authors interpreted and discussed the results. All authors drafted parts of the manuscript. GNB and LAG were major contributors in writing the manuscript. All authors read and approved the final manuscript.

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This study received no funding.

### Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

### **Ethics approval and consent to participate**

The study was conducted according to the Declaration of Helsinki. All protocols were reviewed and approved by the Research Ethics Committee of the São Paulo State University. In advance of their participation, all of the participants were fully informed about the purpose and experimental procedures of the study. All of the participants completed consent forms. The participants were informed that all data collected would be processed anonymously.

### **Consent for publication**

Not applicable.

### **Competing interests**

The authors declare that they have no competing interests.

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