CLINICAL SCIENCE

The influence of anthropometric factors on postural balance: the relationship between body composition and posturographic measurements in young adults

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OBJECTIVE: The aim of the present study was to evaluate the influence of anthropometric characteristics and gender on postural balance in adults. One hundred individuals were examined (50 males, 50 females; age range 20-40 years).

METHODS: The following body composition measurements were collected (using bone densitometry measurements): fat percentage (% fat), tissue (g), fat (g), lean mass (g), bone mineral content (g), and bone mineral density (g/cm^2). In addition, the following *anthropometric* measurements were collected: body mass (kg), height (cm), length of the trunk-cephalic region (cm), length of the lower limbs (cm) and length of the upper limbs (cm). The following indices were calculated: body mass index (kg/m^2), waist-hip ratio and the support base (cm^2). Also, a postural balance test was performed using posturography variables with open and closed eyes.

RESULTS: The analysis revealed poor correlations between postural balance and the anthropometric variables. A multiple linear regression analysis demonstrated that the whole group (female and male) height explained 12% of the medial-lateral displacement, 10% of the speed of oscillation, and 11% of the displacement area. The length of the trunk-cephalic length explained 6% of the displacement in the anteroposterior direction. With eyes closed, the support base and height explained 18% of the medial displacement, and the lateral height explained 10% of the displacement speed and 5% of the scroll area.

CONCLUSION: Measured using posturography, the postural balance was only slightly influenced by the anthropometric variables, both with open and closed eyes. Height was the anthropometric variable that most influenced postural balance, both in the whole group and separately for each gender. Postural balance was more influenced by anthropometric factors in males than females.

KEYWORDS: Assessment; Postural Balance; Anthropometry; Sensorimotor Performance; Young Adult.

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INTRODUCTION

Many balance assessment methods exist, including simple observations, clinical tests, scales, posturographic measurements and integrated assessment systems of greater complexity. They all have advantages and limitations and can produce different results with multiple interpretations. This diversity is worsened by the lack of consensus regarding which individual characteristics (particularly anthropometric factors) must be controlled to ensure the reliability of the quantitative evaluations. In clinical practice, this lack of consensus impedes using these tests as a safe tool for assessing the risk of falls and the results of therapeutic interventions (1-8).

Studies using various assessment tools in various populations have shown that as body mass increases, balance worsens. Studies have been conducted on groups of prepubescent children and adolescents (9,10), adults (11-15), and elderly people (16,17) who were obese or extremely obese, and in all of these populations, body mass influenced postural stability.

Evaluations that were performed on stable surfaces with individuals who were overweight or with normal body mass indices (BMI) have shown that balance does not appear to be affected in such situations (6,18,19). However, in situations that combine instability (20) and extreme BMI, postural balance worsens (10).

No potential conflict of interest was reported.

A number of questions remain unanswered in the literature. Do anthropometric factors interfere with postural balance in young adults with normal or slightly higher BMIs? Can body composition better explanation for the variations encountered, and should these variables be considered during balance assessments?

The aim of the present study was to evaluate the influence of anthropometric characteristics and gender on postural balance in irregularly active adults placed in an erect semi-static position standing on two feet with the eyes open and closed.

METHODS

The study evaluated 100 males and females aged 20-40 years who were irregularly physically active. The participants provided written informed, and the study was approved by the Faculdade de Medicina da Universidade de São Paulo (no. 1256/06).

The following inclusion criteria were applied: no history of injury to or surgery on the lower limbs and trunk, irregularly active over the last six months, as defined by the International Physical Activity Questionnaire, the absence of disease or functional impairment of the auditory, vestibular and proprioceptive systems, and no current use of medications that might alter postural balance. Patients who were unable to carry out the postural balance tests were excluded.

The characteristics of the individuals who participated in the study are described in Table 1.

The anthropometric measurements were made in accordance with the ISAK standard (21). The BMI (kg/m^2) and the waist-hip ratio (cm) were calculated. The support base area (cm^2) was evaluated with the individual placed in an upright position and standing on both feet with a comfortable separation but without exceeding the shoulder width. This distance was recorded on a piece of paper and served as the baseline for all of the tests. To calculate the support base area, the formula described by Chiari et al. was used (18).

Figure 1 - AccuSway^{Plus} portable force platform.

Body composition was assessed using bone densitometry with a dual energy X-ray absorptiometry (DEXA) on a LUNAR-DPX apparatus (Madison Corporation, USA).

The postural balance assessment (posturography) was performed on a portable force platform (AccuSway Plus, AMTI®, MA, USA) (Figure 1). The data were gathered and stored using the Balance Clinic® software, configured to a frequency of 100 Hz with a fourth-order Butterworth filter and a cutoff frequency of 10 Hz. All of the subjects assumed

Table 1 - Characteristics of the study population (anthropometric and posturographic).

Variables	*Whole group Mean (SD) N = 100*	*Female group Mean (SD) N = 50*	*Male group Mean (SD) N = 50*
Age (years)	27.2 (5.7)	26.4 (5.1)	28.0 (6.1)
Anthropometrics			
Height (cm)	168.8 (9.5)	161.8 (6.8)	175.8 (6.2)
Body mass (kg)	69.9 (14.3)	61.2 (10.9)	78.6 (11.8)
BMI (kg/m^2)	24.3 (3.6)	23.2 (3.7)	25.3 (3.3)
Upper-limb length (cm)	168.9 (11.9)	160.3 (8.3)	177.4 (8.3)
Trunk-cephalic length (cm)	89.9 (4.4)	87.6 (3.3)	83.6 (5.3)
Lower-limb length (cm)	79.0 (6.7)	74.3 (4.4)	83.6 (5.3)
Support base area (cm^2)	322.3 (59.8)	306.0 (56.7)	338.6 (58.9)
% fat	30.2 (10.1)	37.3 (6.6)	23.1 (7.7)
Soft tissue (g)	67231.5 (13911.0)	58997.9 (10745)	75465.2 (11711)
Fat (g)	20297.1 (8029.9)	22483.4 (7515)	18110.9 (8002.6)
Lean mass (g)	46934.4 (11888.3)	36514.6 (4963)	57354.3 (6271.7)
Bone mineral composition (g)	2774.6 (551.9)	2347.5 (333)	3201.7 (363.5)
Bone mineral density (g/cm^2)	1198.0 (92.3)	1142.0 (67.9)	1254.0 (78.8)
Waist-hip ratio (cm)	81.7 (7.6)	77.9 (7.6)	86 (0.5)
Posturographic measurements (log$_{10}$)			
Eyes open			
Mediolateral displacement (cm)	-0.685 (0.154)	-0.716 (0.14)	-0.653 (0.16)
Anteroposterior displacement (cm)	-0.421 (0.128)	-0.429 (0.13)	-0.412 (0.11)
Sway velocity (cm/s)	-0.130 (0.097)	-0.153 (0.09)	-0.107 (0.09)
Displacement area (cm^2)	0.140 (0.243)	0.106 (0.25)	0.173 (0.23)
Eyes closed			
Mediolateral displacement (cm)	-0.612 (0.161)	-0.629 (0.17)	-0.594 (0.15)
Anteroposterior displacement (cm)	-0.332 (0.148)	-0.328 (0.17)	-0.337 (0.12)
Sway velocity (cm/s)	0.008 (0.110)	-0.008 (0.10)	0.026 (0.10)
Displacement area (cm^2)	0.306 (0.259)	0.294 (0.28)	0.317 (0.23)

Legend: cm - centimeters; kg - kilograms; g - grams; cm^2 – square centimeters; % - percentage; BMI - body mass index; SD - standard deviation.

a standing position on two feet, with their arms suspended alongside their bodies and their eyes fixed on a point that was located one meter away. Three measurements were made with the eyes open and three with the eyes closed (60 seconds each). The arithmetic means of the results were calculated from the three tests conducted under each condition. The following parameters were used to measure the stability of the subjects with their eyes open (EO) and eyes closed (EC): the root mean square of the displacements from the center of pressure (COP) in the mediolateral (XSD) and anteroposterior planes (YSD), the mean velocity calculated from the total displacement of the COP in all directions (VAvg) and the elliptical area encompassing 95% of the displacement from the COP.

Statistical analysis

The data were stored and analyzed using the SPSS 17.0 software (IBM, Chicago, USA). The Kolmogorov-Smirnov test was used to ascertain whether the continuous variables presented normal distributions; the variables that did not present normal distributions were transformed into $\log_{10}$.

Pearson's correlation coefficient was used to assess the correlations between the dependent variables (the posturographic parameters) and the independent variables (the anthropometric measurements and age) in the whole population and by gender.

A linear regression model analysis was performed by selecting all of the variables that presented $p \leq 0.20$ in the correlation coefficient analysis. These variables were then ranked from the lowest to highest *p*-value. A multiple modeling process using stepwise forward selection was conducted, and the variables were added to the model one by one, according to their ranking. The variables with $p \leq 0.05$ were kept in the model.

RESULTS

Correlation analysis

The correlation coefficients between the postural balance variables and the anthropometric variables in the whole group (male and female) were divided according to gender under the ''eyes open'' condition, as shown in Table 2.

Whole group: Height, trunk-cephalic length and bone mineral composition significantly correlated with all of the balance variables.

Female group: None of the anthropometric variables correlated with all of the balance variables.

Male group: Height was the only variable that was significantly correlated with all of the balance variables.

The correlation coefficients between the postural balance variables and the anthropometric variables in the whole group (male and female) were divided by gender under the ''eyes closed'' condition, as shown in Table 3.

Whole group and male group: Height was the only variable that was significantly correlated with all of the balance variables.

Female group: None of the anthropometric variables were correlated with all of the balance variables.

Regression analysis

The regression analyses of the anthropometric variables in relation to the postural balance variables in the whole group with the eyes open and closed are described in Table 4.

Whole group

''Eyes open''

- Height explained 12% of the mediolateral displacement, 10% of the sway velocity and 11% of the displacement area.
- Trunk-cephalic length explained 6% of the anteroposterior displacement.

''Eyes closed''

- Height and support base area explained 18% of the mediolateral displacement.
- Trunk-cephalic length explained 10% of the displacement velocity and 5% of the displacement area.

Female group

''Eyes open''

- Height and bone mineral density explained 16% of the anteroposterior displacement.

''Eyes closed''

- Upper-limb length explained 15% of the mediolateral displacement.
- Age explained 5% of the anteroposterior displacement.

Male group

''Eyes open''

- Height explained 14% of the mediolateral displacement and 15% of the sway velocity.
- Lean mass explained 18% of the anteroposterior displacement and 18% of the displacement area.

''Eyes closed''

- Height and support base area explained 28% of the mediolateral displacement.
- Lean mass explained 10% of the anteroposterior displacement.
- Lower-limb length and waist-hip ratio explained 26% of the sway velocity.
- Mean mass and support base area explained 25% of the sway area.

DISCUSSION

Age is not an anthropometric variable, but it is an important factor in assessing postural balance. However, it was not important in the present study of young adults, and this finding was consistent with other studies (5,13,22,23).

Among the women with EC, older age correlated with greater anteroposterior sway and explained 5% of the performance. Hue et al. (13) have stated that under challenging conditions, increased age worsens balance. When vision is suppressed, greater participation is required from other body systems (e.g., sensory-motor and vestibular),

Table 2 - Correlations between balance and the anthropometric variables in the whole group and by gender, with eyes open.

Variables	Mediolateral displacement (log_{10})			Anteroposterior displacement (log_{10})			Sway velocity (log_{10})			Displacement area (log_{10})		
	Whole group r (p)	Female group r (p)	Male group r (p)	Whole group r (p)	Female group r (p)	Male group r (p)	Whole group r (p)	Female group r (p)	Male group r (p)	Whole group r (p)	Female group r (p)	Male group r (p)
Age (years)	0.09 (0.37)	0.02 (0.85)	0.09 (0.52)	0.04 (0.63)	-0.01 (0.92)	0.09 (0.52)	0.09 (0.37)	-0.02 (0.84)	0.13 (0.35)	0.07 (0.47)	0.003 (0.98)	0.10 (0.45)
Height (cm)	0.36 (0.000)*	0.24 (0.08)	0.40 (0.004)*	0.28 (0.005) *	0.35 (0.01)*	0.32 (0.02)*	0.33 (0.001)*	0.08 (0.54)	0.40 (0.003)*	0.35 (0.00)*	0.33 (0.01)*	0.41 (0.003)*
Mass (kg)	0.21 (0.03)*	-0.04 (0.74)	0.23 (0.09)	0.24 (0.01) *	0.07 (0.61)	0.45 (0.001)*	0.15 (0.11)	-0.17 (0.22)	0.19 (0.17)	0.23 (0.02)*	0.001 (0.99)	0.36 (0.009)*
BMI (kg/m^2)	0.02 (0.81)	-0.11 (0.41)	0.03 (0.79)	0.12 (21)	-0.06 (0.63)	0.34 (0.01)*	-0.05 (0.57)	-0.24 (0.08)	-0.01 (0.91)	0.06 (0.54)	-0.12 (0.40)	0.19 (0.18)
Upper-limb length (cm)	0.28 (0.005)*	0.04 (0.78)	0.33 (0.01)*	0.20 (0.03) *	0.21 (0.13)	0.24 (0.08)	0.29 (0.002)*	0.10 (0.46)	0.27 (0.05)*	0.26 (0.007)*	0.16 (0.25)	0.33 (0.01)*
Trunk-cephalic length (cm)	0.21 (0.02)*	0.06 (0.65)	0.18 (0.20)	0.27 (0.006) *	0.32 (0.01)*	0.24 (0.09)	0.24 (0.01)*	0.11 (0.42)	0.16 (0.25)	0.24 (0.01)*	0.22 (0.11)	0.20 (0.16)
Lower-limb length (cm)	0.32 (0.001)*	0.18 (0.20)	0.32 (0.02)*	0.17 (0.08)	0.19 (0.18)	0.16 (0.24)	0.29 (0.003)*	0.01 (0.93)	0.32 (0.01)*	0.28 (0.004)*	0.20 (0.15)	0.31 (0.02)*
Support base area (cm^2)	-0.13 (0.17)	-0.19 (0.17)	-0.21 (0.13)	0.02 (0.79)	0.006 (0.96)	0.012 (0.93)	-0.09 (0.36)	-0.12 (0.40)	-0.21 (0.11)	-0.087 (0.38)	-0.10 (0.48)	0.16 (0.26)
% fat	-0.23 (0.019)*	-0.26 (0.06)	0.03 (0.82)	-0.03 (0.73)	-0.14 (0.33)	0.17 (0.21)	-0.26 (0.009)*	-0.23 (0.10)	-0.05 (0.71)	-0.14 (0.15)	-0.21 (0.13)	0.07 (0.60)
Soft tissue (g)	0.20 (0.038)*	-0.04 (0.76)	0.23 (0.10)	0.24 (0.01) *	0.08 (0.56)	0.44 (0.001)*	0.16 (0.10)	-0.15 (0.29)	0.19 (0.18)	0.23 (0.02)*	0.008 (0.95)	0.36 (0.009)*
Fat (g)	-0.10 (0.30)	-0.17 (0.23)	0.04 (0.75)	0.10(0.30)	-0.02 (0.86)	0.29 (0.03)*	-0.14 (0.16)	-0.20 (0.16)	0.03 (0.82)	-0.00 (0.960)	-0.11 (0.44)	0.18 (0.20)
Lean mass (g)	0.31 (0.001)*	0.16 (0.24)	0.37 (0.007)*	0.21 (0.03) *	0.22 (0.12)	0.45 (0.001)*	0.28 (0.004)*	-0.02 (0.83)	0.31 (0.02)*	0.27 (0.006)*	0.18 (0.19)	0.44 (0.001)*
Bone mineral composition (g)	0.26 (0.008)*	0.01 (0.93)	0.29 (0.03)*	0.22 (0.02) *	0.19 (0.16)	0.35 (0.01)*	0.19 (0.05)*	-0.16 (0.26)	0.15 (0.27)	0.24 (0.01)*	0.10 (0.45)	0.32 (0.02)*
Bone mineral density (g/cm^2)	0.12 (0.21)	-0.01 (0.91)	0.01 (0.93)	0.007 (0.94)	-0.15 (0.27)	0.07 (0.63)	0.02 (0.81)	-0.25 (0.07)	-0.07 (0.60)	0.04 (0.67)	-0.12 (0.39)	0.009 (0.95)
Waist-hip ratio (cm)	0.26 (0.08)*	0.24 (0.08)	0.12 (0.39)	0.07 (0.43)	0.08 (0.95)	0.10 (0.48)	0.18 (0.06)	-0.12 (0.39)	0.24 (0.09)	0.17 (0.08)	0.09 (0.49)	0.13 (0.35)

Pearson's coefficient (r); * $p \leq 0.05$.
Legend: cm - centimeters; kg - kilograms; g - grams; cm^2 - square centimeters; % - percentage; BMI - body mass index.

Table 3 - Correlations between balance and the anthropometric variables in the whole group and by gender, with eyes closed.

Variables	Mediolateral displacement (log_{10})			Anteroposterior displacement (log_{10})			Sway velocity (log_{10})			Displacement area (log_{10})		
	Whole group r (p)	Female group r (p)	Male group r (p)	Whole group r (p)	Female group r (p)	Male group r (p)	Whole group r (p)	Female group r (p)	Male group r (p)	Whole group r (p)	Female group r (p)	Male group r (p)
Age (years)	0.10 (0.30)	-0.01 (0.90)	0.18 (0.19)	0.10 (0.28)	-0.27 (0.05)*	0.08 (0.56)	0.09 (0.36)	-0.14 (0.30)	0.25 (0.07)	-0.002 (0.98)	-0.16 (0.25)	0.15 (0.29)
Height (cm)	0.35 (0.000)*	0.44 (0.001)*	0.40 (0.004)*	0.05 (0.56)	0.09 (0.52)	0.15 (0.27)	0.31 (0.001)*	0.17 (0.21)	0.44 (0.001)*	0.25 (0.01)*	0.29 (0.04)*	0.35 (0.01)*
Mass (kg)	0.22 (0.02)*	0.12 (0.39)	0.26 (0.06)	0.08 (0.42)	-0.03 (0.79)	0.33 (0.01)*	0.17 (0.08)	-0.09 (0.53)	0.27 (0.05)*	0.18 (0.07)	0.06 (0.67)	0.35 (0.01)*
BMI (kg/m^2)	0.04 (0.69)	-0.04 (0.75)	0.07 (0.60)	0.06 (0.53)	-0.06 (0.64)	0.29 (0.04)*	-0.02 (0.84)	-0.19 (0.18)	0.06 (0.64)	0.06 (0.50)	-0.04 (0.74)	0.19 (0.17)
Upper-limb length (cm)	0.32 (0.001)*	0.40 (0.003)*	0.30 (0.03)*	0.03 (0.70)	0.05 (0.70)	0.13 (0.36)	0.29 (0.003)*	0.26 (0.06)	0.26 (0.05)*	0.21 (0.03)*	0.25 (0.07)	0.27 (0.05)*
Trunk-cephalic length (cm)	0.21 (0.03) *	0.24 (0.09)	0.14 (0.30)	0.05 (0.60)	0.16 (0.26)	-0.002 (0.99)	0.16 (0.09)	0.16 (0.24)	0.05 (0.70)	0.16 (0.10)	0.21 (0.13)	0.12 (0.40)
Lower-limb length (cm)	0.32 (0.001)*	0.38 (0.005)*	0.32 (0.02)*	0.02 (0.81)	-0.03 (0.83)	0.17 (0.23)	0.32 (0.001)*	0.10 (0.47)	0.46 (0.001)*	0.20 (0.04)*	0.18 (0.18)	0.30 (0.03)*
Support base area (cm^2)	-0.15 (0.12)	0.003 (0.98)	-0.38 (0.006)*	0.02 (0.79)	0.04 (0.78)	0.03 (0.82)	-0.02 (0.82)	-0.01 (0.94)	-0.12 (0.38)	-0.09 (0.35)	0.02 (0.88)	-0.26 (0.06)
% fat	-0.12 (0.22)	-0.12 (0.40)	-0.01 (0.90)	-0.002 (0.98)	-0.12 (0.38)	0.07 (0.59)	-0.18 (0.06)	-0.12 (0.38)	-0.01 (0.93)	-0.05 (0.59)	-0.12 (0.39)	0.04 (0.75)
Soft tissue (g)	0.22 (0.02)*	0.12 (0.39)	0.26 (0.06)	0.08 (0.38)	-0.02 (0.86)	0.33 (0.01)*	0.17 (0.07)	-0.06 (0.63)	0.27 (0.05)*	0.18 (0.06)	0.06 (0.63)	0.35 (0.01)*
Fat (g)	0.01 (0.87)	0.013 (0.92)	0.08 (0.57)	0.06 (0.54)	-0.06 (0.63)	0.22 (0.12)	-0.06 (0.54)	-0.13 (0.366	0.08 (0.54)	0.06 (0.54)	-0.009 (0.94)	0.17 (0.21)
Lean mass (g)	0.24 (0.01)*	0.24 (0.08)	0.39 (0.005)*	0.06 (0.54)	0.05 (0.72)	0.34 (0.01)*	0.25 (0.01)*	0.04 (0.73)	0.39 (0.004)*	0.17 (0.08)	0.16 (0.25)	0.42 (0.002)*
Bone mineral composition (g)	0.22 (0.02)*	0.24 (0.08)	0.22 (0.12)	-0.002 (0.98)	-0.03 (0.81)	0.12 (0.40)	0.16 (0.09)	-0.11 (0.44)	0.24 (0.09)	0.13 (0.17)	0.12 (0.40)	0.21 (0.14)
Bone mineral density (g/cm^2)	0.07 (0.47)	0.12 (0.39)	-0.09 (0.51)	-0.11 (24)	-0.18 (0.20)	-0.06 (0.65)	0.03 (0.71)	-0.18 (0.19)	0.02 (0.89)	-0.02 (0.83)	-0.03 (0.79)	-0.08 (0.54)
Waist-hip ratio (cm)	0.25 (0.01) *	0.25 (0.07)	0.23 (0.09)	0.02 (0.81)	0.04 (0.76)	0.07 (0.62)	0.18 (0.06)	-0.07 (0.62)	0.32 (0.02)*	0.16 (0.09)	0.14 (0.30)	0.21 (0.13)

Pearson's coefficient (r); * $p \leq 0.05$. **Legend**: cm - centimeters; kg - kilograms; g - grams; cm^2 - square centimeters; % - percentage; BMI - body mass index.

Table 4 - Linear regression analysis on postural balance and the anthropometric variables for the whole group and per gender, with eyes open and closed.

Group condition / Variables	Height	Trunk-cephalic length	Support base area	Bone mineral density	Upper-limb length	Age	Lean mass	Lower-limb length	Waist-hip ratio	r^2
	β (*p*)	β (*p*)	β (*p*)	β (*p*)	β (*p*)	β (*p*)	β (*p*)	β (*p*)	β (*p*)	adjust
Whole group										
Eyes open										
Mediolateral displacement	+0.006 (<0.001)	-	-	-	-	-	-	-	-	0.12
Anteroposterior displacement		+0.008 (0.006)	-	-	-	-	-	-	-	0.06
Sway velocity	+0.003 (0.001)	-	-							0.10
Displacement area	+0.009 (<0.001)	-	-	-	-	-	-	-	-	0.11
Eyes closed										
Mediolateral displacement	+0.007 (<0.001)	-	+00.001 (<0.001)	-	-	-	-	-	-	0.18
Anteroposterior displacement	-	-	-	-	-	-	-	-	-	
Sway velocity	-	+0.004 (<0.001)	-	-	-	-	-	-	-	0.10
Displacement area	-	+0.007(0.01)	-	-	-	-	-	-	-	0.05
Female group										
Eyes open										
Anteroposterior displacement	+20.396 (0.01)			-0.001 (0.04)	-	-	-	-	-	0.16
Eyes closed										
Mediolateral displacement					0.004 (<0.001)					00.15
Anteroposterior displacement	-	-	-	-	-	0.009 (0.05)		-	-	0.05
Male group					-	-				
Eyes open							-			
Mediolateral displacement	+0.011 (<0.001)		-					-	-	0.14
Anteroposterior displacement	-		-					-	-	0.18
Sway velocity	+0.006 (<0.001)		-					-	-	0.15
Displacement area	-		-					-	-	0.18
Eyes closed										
Mediolateral displacement	+0.010 (<0.001)		-0.001 (<0.001)					-	-	0.28
Anteroposterior displacement			-				+60.788 (0.01)	-	-	0.10
Sway velocity			-				-	+0.009 (<0.001)	+0.537 (0.03)	0.26
Displacement area			-0.001 (0.01)				+10.731 (<0.001)	-	-	0.25

r^2 – r adjusted; * $p \le 0.05$. **Legend**: β - beta value.

and this factor may explain the need for greater adjustments to maintain balance.

With greater body mass and soft-tissue mass (sum of the lean and fat masses), there was greater mediolateral sway (EO and EC) and anteroposterior sway and displacement area (EO) in the whole group. A separate evaluation of the genders indicated that these variables only correlated among males, which may indicate that the greater body mass in men interfered more with balance than it did in women. This finding was consistent with other studies (6,18,19). This weak correlation, which was observed for some variables and under some conditions, may indicate that semi-static balance among individuals with normal body composition and BMIs does not depend on body mass and soft-tissue mass. In a more challenging situation (EC), the displacement velocity was greater in the male group, which may be associated with the greater male body mass (14).

There was a weak positive correlation between BMI and anteroposterior displacement in the male group (EO and EC). Although this result corroborates the findings from studies of individuals with normal BMIs (6,18,19), it contradicts the findings of Greve et al. (20) who demonstrated that there was a moderate to strong correlation between BMI and balance among young adults on an unstable platform and those of Singh et al. (15) who stated that under extreme conditions (BMI >40 kg/m^2), balance becomes impaired during prolonged activities.

There is a consensus that obesity worsens balance, but Winters and Snow (24) and Mainenti et al. (17) have demonstrated that DEXA and bioimpedance are important for settling controversies because of the less refined nature of body mass and BMI measurements.

The fat percentage was negatively correlated to the mediolateral sway and the displacement velocity in the whole group with eyes open. The fat measurement in grams was only correlated with the anteroposterior movements in the male group. There are few studies of body composition variables for comparative purposes.

In the female group, there was no correlation between the fat mass measurements and the balance parameters, either with EO or with EC. This outcome differed from the findings of Mainenti et al. (17) who observed that elderly women with greater fat mass exhibited worse performance. Winters and Snow (24) reported that 31% of balance variations in premenopausal women who were evaluated on a multidirectional platform was caused by variations in fat mass. Assessments on unstable surfaces require greater motor control and may be more sensitive to variations in body composition than static evaluations (20).

Greater lean mass correlated with significantly greater postural control in relation to all of the balance variables with EO and the mediolateral direction and velocity with EC. These results were observed for the whole group. The male group showed correlations with all of the variables, with EO and EC; however, there were no correlations in the female group. It is possible that this behavioral difference occurred because of differences in body composition or because the women were more skillful in postural control because of habits, footwear and adaptation to a lower level of lean mass. The women may have developed other strategies for maintaining balance that depended less on body composition.

Lean mass explained 18% of the anteroposterior displacement and displacement area among the men. The greater quantity of lean mass with greater development of the musculature among the men was most likely the factor responsible for this effect, in addition to the influence of height. The postural balance among the men may be more dependent on the action of joint and muscle effectors, which might also explain the greater activity.

Under the EC condition, lean mass explained 10% of the anteroposterior displacement and, together with the support base area, 25% of the displacement area. The complexity and multiplicity of postural control may explain this correlation (i.e., the greater the lean mass and the smaller the support base area, the greater the displacement and sway area), but these movements are capable of balancing an individual. These findings should not be viewed as a worsening of balance and a risk of falling but rather as one of the strategies used to maintain the center of pressure within the area of stability.

The greater the waist-hip ratio, the worse the postural balance in the mediolateral direction (under both conditions evaluated and in the whole sample). In the male group with EC, the greater the waist-hip ratio, the greater the sway velocity. The waist-hip ratio and the upper-limb length explained 26% of the postural balance, and this result was similar to the findings of Menegoni et al. (14). It is possible that a concentration of fat mass in the chest and abdomen (android shape) increases the load on the hips, thereby explaining the greater displacement in the mediolateral direction. A centripetal fat distribution changes the center of mass, which ends up being greater in android than in gynoid shapes.

The bone mineral density and height explained 16% of the postural balance in the anteroposterior direction. Bone mineral density has been correlated with loading and impact on bones, and it is reasonable to assume that this correlation would have some influence on balance. Winters and Snow (24) correlated bone mineral density with anthropometric variables and found an interrelation between these variables, but they reported that it did not influence postural balance.

Bone mineral composition was shown to have a positive correlation with all of the variables in the whole group and in the male group, except for sway velocity with the EO. With the EC, there was a positive correlation with the mediolateral displacement in the whole group. Lower bone mineral density and bone mineral composition values combined with poor balance increases the risk of fractures from falls, but no relationship between these measurements and balance was found in the present study nor in the literature.

The smaller the support base area, the greater the mediolateral sway in the male group with EC. A larger support base area increased the balance and decreased the postural control activity, and these findings were consistent with those of other authors (18,25-27).

The support base area and height explained 18% of the variation in balance in the mediolateral direction in the whole group and 28% of that in the male group. The relationship between height and support base area in the male group (whose measurements were larger than those in the female group) can be understood through the inverse relationship between postural stability and the height of the center of gravity. Widening the support base area decreases the distance from the center of gravity to the base and improves stability.

There is a consensus in the literature, which was also observed in the present study, that increased height worsens balance (5,13,16). Height showed a positive correlation with all of the balance variables in the whole group and in the male group with the EO, as well as with anteroposterior displacement in the female group with the EO and EC. In the whole group and in the male group with EC, height correlated with mediolateral displacement, velocity and area. In the regression analysis, height explained half of the variation in balance. Berger et al. (28) have stated that ankle displacement and the response of the gastrocnemius increased with increasing height. Allardy et al. (29) and Lee and Lin (30) have reported that ectomorph individuals presented greater postural sway than that shown by endomorph and mesomorph individuals; the authors attributed this difference to a higher center of mass. The greater height in the male group may explain the greater influence of this parameter on balance, in comparison with the female group.

The lengths of the upper and lower limbs showed positive correlations with mediolateral displacement, sway velocity and displacement with both EO and EC. In the male group, the upper-limb length and the waist-hip ratio together explained 26% of the balance. In the female group with the EC, there was a correlation between mediolateral displacement and the upper-limb length, which explained 15% of the balance. Molikova et al. (6) have reported that in flexed-knee positions (30˚ and 60˚), the upper limbs exerted a greater influence on the postural balance. The limbs generally follow the format of the body because taller individuals tend to have longer limbs, and a similar correlation can be derived from this association. A greater upper-limb length is correlated with a greater distance between the center of mass and the support base area, similarly to height (5,6,16).

The greater the trunk-cephalic length, the worse the balance in relation to all of the variables in the whole group with the EO. With the EC, the mediolateral displacement is possibly related to height (16). In the female group, there was a positive correlation between balance and anteroposterior displacement, which may have been related to the gynoid shape and longer trunk; this difference made balance more difficult for the women because more adjustments were required.

In our study population of healthy and normal young adults, the anthropometric parameters had little influence on balance. It does may not be necessary to take anthropometric variables into consideration in studies of static balance using posturography in such populations, with the exception of height.

There are methodological limitations caused by the particular multifactorial characteristics of balance. Systems that make integrated assessments of vision, labyrinth activity, and the neuromotor responses associated with posturography and center-of-pressure analysis may be more appropriate for assessing balance in the evaluations of other systems and in assessing situations that are more challenging.

Postural balance measured using posturography was little influenced by anthropometric variables, both with the eyes open and closed.

Height was the anthropometric variable that most influenced postural balance in the whole group and grouped by gender.

Postural balance was more influenced by anthropometric factors in the male group.

AUTHOR CONTRIBUTIONS

Alonso AC conceived the project and participated in the construction of all the phases. Luna MN and Santos S assisted in the data collection and in the manuscript drafting. Mochizuki L assisted in the data analysis and in the final correction of the manuscript. Barbieri F conducted the densitometry examinations and assisted in the data interpretation. D'Andréa Greve JM organized the work.

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