CLINICAL SCIENCE

Adiposity and postural balance control: Correlations between bioelectrical impedance and stabilometric signals in elderly Brazilian women

Míriam Raquel Meira Mainenti, Érika de Carvalho Rodrigues, Juliana Flávia de Oliveira, Arthur de Sá Ferreira, Cristina Márcia Dias, André Luís dos Santos Silva

Augusto Motta University Center (UNISUAM) - Postgraduate Program of Rehabilitation Sciences, Rio de Janeiro, Brazil.

OBJECTIVE: The purpose of this study was to investigate the correlation between body adiposity and postural control in elderly women.

INTRODUCTION: Aging and obesity account for a significant portion of healthcare spending. Life expectancy is increasing worldwide, and Rio de Janeiro has the largest proportion of elderly residents of all Brazilian states.

METHODS: A total of 45 women underwent bioelectrical impedance analysis, waist circumference measurements, weight and height measurements, and stabilometric tests in eight different stance conditions (opened and closed bases with both eyes opened and closed and right and left tandem and unilateral stances with eyes opened). During unilateral stances, the number of hand or foot contacts was counted.

RESULTS: Weight, body mass index, waist circumference, fat percentage, and fat mass showed statistically significant ($p<0.05$) and positive correlations with the number of contacts made during unilateral stances. The subjects with greater fat mass showed significantly higher anterior-posterior standard deviation and range when their eyes were closed. The sway area was also greater for this group in opened base when their eyes were closed.

DISCUSSION: The results relating body adiposity and postural control can be explained by the difficulty of maintaining a greater quantity of body fat mass within the limits of the individual support base, especially while assuming a unilateral stance.

CONCLUSION: The subjects with a greater fat mass exhibited poor balance control, indicating that body adiposity level was associated with postural control in the elderly women examined in the present study.

KEYWORDS: Body composition; Body fat distribution; Biomechanics; Musculoskeletal equilibrium; Aging.

Mainenti MRM, Rodrigues EC, Oliveira JF, Ferreira AS, Dias CM, Silva ALS. Adiposity and postural balance control: Correlations between bioelectrical impedance and stabilometric signals in elderly Brazilian women. Clinics. 2011;66(9):1513-1518.

Received for publication on January 25, 2011; **First review for publication on** March 28, 2011; **Accepted for publication on** May 12, 2011

E-mail: miriam.mainenti@hotmail.com

Tel.: 55 21 3882-9841

INTRODUCTION

The number of individuals over age 60 is increasing worldwide. In Rio de Janeiro, Brazil, 12.8% of the population is considered to be elderly, and nationwide statistics show that the number of elderly people living alone increased by 16% between 1991 and 2000.[1] The number of obese individuals in Brazil is also increasing; 38.8 million Brazilian adults are either overweight or obese, corresponding to 40% of the adult population.[2] In the United States, 66.3% of all adults over 20 years old and 71% of those over 60 years old are overweight or obese.[3] It has been well established that aging is associated with modifications in body composition, including decreased lean mass[4,5] and increased truncal fat.[6] This ''sarcopenic obesity'' influences normal walking speed and mobility disability,[7] modifies balance control,[8] and decreases stability limits in those with advanced obesity.[9]

The body mass index (BMI) is a simple proportion of weight-for-height that is commonly used to classify individuals as overweight or obese. Despite the fact that it is a widely accepted measurement,[10] BMI is unable to separately quantify body fat composition. The use of body fat measures instead of weight measures is preferable for determining an individual's possible health risks for cardiovascular diseases even when weight is corrected for height. The bioelectrical impedance method is a fast, noninvasive, easy-to-implement, and low-cost technique that is used to estimate body fat.[11] This method requires little collaboration from the patient and reduces inter- and intra-observer errors;[11] in addition, the equipment is lightweight, portable, and produces fast results.[12] In this method, an imperceptible electric current is applied via surface electrodes and passes through the body; the conductance is then measured. Impedance measurements allow fat-free mass and fat mass to be estimated using validated equations.[11,13] Another measurement that is positively correlated with intra-abdominal fat mass is waist circumference, which constitutes a simple method of fat mass measurement that is frequently used by health professionals. Waist circumference is strongly associated with truncal fat, regardless of the site of measurement chosen,[14] and increases with age.[15]

Quiet standing postural control is possible, due to the integration of different sensory systems that deliver information to the central nervous system about how body parts are placed relative to the environment. Stabilometry, an objective method used to evaluate body stability, measures successive two-dimensional coordinates based on the center-of-foot pressure on a force platform and calculates a variety of variables.[16] One of the most dangerous aspects of changes in body stability for the elderly is an increased risk of falls. This concern explains the focus on postural balance and aging in the literature over the last ten years;[17-21] many researchers have attempted to understand which characteristics significantly disturb balance control and, consequently, tend to increase the incidence of falls.

The evaluation of the relationship between balance and adiposity in elderly subjects is important for providing information to health professionals about the characteristics that influence balance control. Aging and obesity are conditions that account for a significant portion of healthcare spending.[22] Therefore, this research may promote progress in the treatment and prevention of falls, indirectly enhancing the quality of life of elderly individuals. The aim of the present study was to investigate the association between body adiposity as analyzed by body composition and distribution measurements and postural control in elderly women living in Rio de Janeiro, Brazil. It was hypothesized that subjects with a higher level of body adiposity would have a greater center-of-foot pressure displacement during quiet stance.

MATERIALS AND METHODS

Study Protocol and Subjects

This cross-sectional study evaluated 45 women enrolled in the program ''Open University for the Elderly'' *(Universidade Aberta à Terceira Idade, UNATI)* at the Augusto Motta University Center (*Centro Universitário Augusto Motta, UNISUAM*) in Bonsucesso, a northern region of Rio de Janeiro, Brazil. Inclusion criteria were as follows: women over 60 years old who were participating in the UNATI program. For exclusion purposes, all of the elderly women underwent a screening evaluation before the main evaluation, which was conducted by the examiner. Exclusion criteria were as follows: 1) the presence of any implantable electronic or metallic device, such as a pacemaker; 2) musculoskeletal impairments, such as hip or knee pain during 60 seconds of orthostatic posture; 3) neurological diseases, such as stroke, Parkinson disease, Alzheimer disease and amyotrophic lateral sclerosis; 4) acute dizziness; 5) abnormal accumulation of fluid (edema), mainly in the limbs, as assessed by physical examination (inspection and palpation); and 6) when the recommendations described below were not followed.

Recommendations and Preliminary Evaluations

Body composition and stabilometric assessments were carried out at the Laboratory of Human Movement Analysis (Postgraduate Program of Rehabilitation Sciences, UNISUAM). When the evaluation was scheduled, the following recommendations were discussed with each subject: 1) no alcohol consumption or exercise within 24 hours prior to taking the test; 2) no caffeine or food consumption for four hours prior to the test; 3) the consumption of two-four glasses of water within the two hours prior to the test; 4) bathroom use within the 30 minutes prior to the assessment.

The subjects' weight, rounded to the nearest 0.1 kg, was measured using an analog balance scale (R110, Welmy, Santa Bárbara d'Oeste, São Paulo, Brazil), and the subjects' height, rounded to the nearest 0.005 m, was also assessed using this device, which includes a stadiometer. Using the weight and height measurements, the subject's BMI was calculated using the standard method (BMI = Weight/ Height^2).[10] Lower limb dominancy was also assessed by asking subjects which leg they preferred to use for kicking a ball.

Bioelectrical Impedance Analysis

Body composition analysis was performed using a bioelectrical impedance analyzer (BIA 310e, Biodynamics, Seattle, Washington, USA). The test current was set at 800 µA and 50 kHz, which were well below the Association for Advancement of Medical Instrumentation's standard for "Safe Current Limits". The tetrapolar resistance and reactance measurements were collected in a standardized manner; the subjects were asked to rest for five minutes prior to the exam on an examination table. They stood barefoot without any metal objects close to them, and the feet and hands were at least 30 cm and 15 cm apart, respectively. Two electrodes were applied to the dorsal surface of the right hand, and two electrodes were placed on the dorsal surface of the right foot. Resistance and reactance provided by the analyzer were used to estimate the fat-free mass (kg). Additional body composition variables were analyzed, including fat mass (kg) and fat percentage (%). The equation selected to predict the fat-free mass[23] was previously validated in elderly samples,[11,24] including a Brazilian sample of subjects aged 60-81 years:[11]

$$FFM = -4.104 + 0.518\left(H^2/R\right) + 0.231\ (BW) + 0.130\ (Xc) + 4.229\ (G),$$

where FFM = fat-free mass (kg), H = stature (cm), R = resistance (Ω), BW = body weight (kg), Xc = reactance (Ω) and G = gender (0 for females and 1 for males).

Waist circumference was also measured at the narrowest point between the lower costal border and the iliac crest.[25] A flexible steel tape (Terrazul, Cambuci, São Paulo, Brazil) was used to verify this girth to the nearest 0.1 cm.

Stabilometry

Postural sway was quantified using a force platform (AccuSway Plus, AMTI, Watertown, Massachusetts, USA), and center-of-foot pressure signals were recorded using Balance Clinic Software (AMTI, USA). All participants performed the following eight trials: opened base, eyes open (OBEO); opened base, eyes closed (OBEC); closed base, eyes open (CBEO); closed base, eyes closed (CBEC); tandem right, eyes open; tandem left, eyes open; right unilateral stance, eyes open; left unilateral stance, eyes open. They were asked to maintain a standing posture while remaining as still as possible and to look straight ahead at a specific point on the wall at their eye level when their eyes were opened. Each trial lasted 60 seconds, and a randomized block design (four possible sequences of the described trials) was used to minimize fatigue and learning effects. The calculated stabilometric variables included the lateral standard deviation, anterior-posterior standard deviation, lateral range, anterior-posterior range, effective area, path length, and average velocity. During tandem and unilateral stances, the number of foot or hand contacts needed by the subject to avoid a fall was also recorded.

Statistical Analysis

Variable distributions were analyzed using Kolmogorov-Smirnov tests; if a meaningful number of variables did not have a normal distribution, nonparametric tests were selected. Variable values are presented as the median (first - third quartile). The sample was divided into two groups using the fat mass median. The Low Fat Mass Group was comprised of those elderly women with a fat mass ≤29.08 kg. The High Fat Mass Group was comprised of subjects with a fat mass >29.08 kg. Two different analyses were performed; the Low Fat Mass Group was compared with the High Fat Mass Group using the Mann-Whitney Test for numerical variables and the *chi*-square test for categorical variables. The correlation between body composition variables and the number of foot and hand contacts required to avoid falls was evaluated using the Spearman Correlation Test.[26] Statistical Package for Social Sciences (SPSS) 13.0 software for Windows was used for the statistical analysis, and significance was assigned when the *p*-value was less than 0.05.

Ethics

According to the recommendations of the Helsinki Declaration, the protocol was approved by the UNISUAM Ethics Committee (protocol number 003/10), and written informed consent was obtained from all participants before their participation in this study.

RESULTS

General and anthropometric characteristics and body composition variables derived from bioelectrical impedance measurements of the studied sample are presented in Table 1. As expected, the High and Low Fat Mass Groups were statistically different in terms of their weight, BMI, waist circumference, fat percentage, fat mass, and fat-free mass. Subject age, a possible confounding variable, was not statistically different between these groups. There was a considerable number of women with right leg dominance (88.89%) in the sample, and, when separated into Low and High Fat Mass Groups, this pattern was preserved (86.96% and 90.91%, respectively). Although not statistically significantly different, the number of subjects not using any support during right or left unilateral stances was higher in the Low Fat Mass Group (Table 1).

The High Fat Mass Group showed significantly higher values for anterior-posterior standard deviation and range during OBEC and CBEC. The effective area was also greater for this group during OBEC (Table 2). A statistically significant difference in path length and average velocity was not observed between groups in any trial. Right and left tandem variables were analyzed only for those participants who used no foot or hand support to avoid falls. For this reason, the sample size for this investigation was smaller (19 *vs*. 15 and 19 *vs*. 16, respectively) (Table 2).

When the whole sample was considered, fat percentage and fat mass showed significant and positive correlations with the number of contacts during right and left unilateral stances even when controlled for age and height. Weight, BMI, and waist circumference were also statistically correlated with contacts used during left unilateral stance and non-dominant unilateral stance (Table 3). Only eight individuals performed the right unilateral stance without foot or hand contacts, and eleven attained the left unilateral stance without foot or hand contacts. Because the sample size was small (eight and eleven), the stabilometric data were not analyzed for these trials.

DISCUSSION

This study showed that an association exists between body adiposity and postural balance control. Greve and co-workers[8] analyzed the association between BMI and a general instability index in another type of sample (young male subjects), and their results showed a positive correlation that corroborates the data presented here. Barbosa and co-workers[27] evaluated BMI in relation to selected physical performance tasks, and their results showed a significant association between balance and BMI for elderly women (60-79 years old).

Although the studies cited above indicate that a relationship exists between fatness and balance, BMI has a poor diagnostic performance for identifying excess body fat, particularly in the elderly.[28] The distinction between fat and lean mass has considerable importance because these factors are directly associated with the independence of elderly individuals.[11]

A study carried out in Canada showed that by 60 to 69 years of age, the percentage of subjects at high risk for health problems (classified using waist circumference values) was more than twice as high as that of individuals between 20 and 39 years (65% for females).[15] The results reported here revealed a significant association between waist circumference and the number of foot or hand contacts needed by the subject to avoid a fall during left unilateral stance. Whether the association between waist circumference and instability is a result of an increased upper circumference area based on the inverted pendulum model[29] or the increased total mass that must be controlled by the neuromuscular system is still unclear and should be investigated with prospective studies.

Bioelectrical impedance analysis, a method previously used in elderly subjects,[5,11,23] showed a high median fat percentage (44.28%), classifying the group as obese (≥35% for women, independent of age),[30] as observed in other studies evaluating elderly individuals.[5,11] The fat-free mass results were similar to those of another study carried out in

CLINICS 2011;66(9):1513-1518

Table 1 - Anthropometric characteristics of the studied sample.

Variable	Sample (n = 45)	Low Fat Mass Group (n = 23)	High Fat Mass Group (n = 22)
Weight (kg)	67.00 (59.10-77.10)	59.20 (57.50-64.00)	77.10 (70.08-88.78)*
BMI (kg/m^2)	28.08 (25.30-32.60)	25.39 (24.56-26.84)	32.60 (31.05-35.38)*
Age (years)	66 (62-72)	69 (60-73)	66 (62-71)
Waist (cm)	89.00 (82.30-93.50)	82.60 (80.08-87.50)	92.00 (89.20-106.25)*
Fat %	44.28 (41.64-48.44)	42.06 (40.19-43.99)	48.44 (45.18-50.35)*
Fat mass (kg)	29.08 (25.26-36.57)	25.66 (23.39-27.88)	36.57 (32.49-43.36)*
FFM (kg)	37.16 (34.35-39.63)	34.92 (34.12-36.71)	39.61 (37.51-45.88)*
Right leg dominance	40 (88.89%)	20 (86.96%)	20 (90.91%)
Subjects not using support during RUS	8 (17.78%)	6 (26.09%)	2 (9.09%)
Subjects not using support during LUS	11 (24.44%)	7 (30.43%)	4 (18.18%)

Values are expressed as the median (1st – 3rd quartile) for numerical variables and as the absolute number (percentage) for categorical variables.
BMI = Body Mass Index; RUS = right unilateral stance; LUS = left unilateral stance; Fat % = Fat percentage; FFM = Fat-free mass.
*$p<0.05$ (Low Fat Mass Group *vs.* High Fat Mass Group; Mann Whitney Test for numerical variables and *chi*-square test for categorical variables).

southern Brazil[11] but were slightly lower when compared to data collected in a US study,[5] probably due to the use of different equations[11,31] to calculate this variable.

Table 2 - Stabilometric variables for High and Low Fat Mass Groups.

Variable	Trials	Low Fat Mass Group (n = 23)	High Fat Mass Group (n = 22)
X SD (mm)	OBEO	0.21 (0.15-0.24)	0.20 (0.15-0.24)
	OBEC	0.19 (0.16-0.25)	0.25 (0.17-0.39)
	CBEO	0.52 (0.38-0.56)	0.45 (0.36-0.54)
	CBEC	0.63 (0.51-0.76)	0.61 (0.47-0.82)
	Tandem Right	0.62 (0.51-0.74)	0.65 (0.53-0.81)
	Tandem Left	0.60 (0.52-0.76)	0.70 (0.58-0.78)
Y SD (mm)	OBEO	0.37 (0.30-0.39)	0.40 (0.34-0.46)
	OBEC*	0.40 (0.31-0.48)	0.52 (0.45-0.65)
	CBEO	0.54 (0.40-0.62)	0.51 (0.43-0.58)
	CBEC*	0.52 (0.45-0.58)	0.66 (0.54-0.72)
	Tandem Right	0.74 (0.51-0.97)	0.65 (0.39-0.77)
	Tandem Left	0.52 (0.44-0.88)	0.67 (0.52-1.02)
X Range (mm)	OBEO	1.07 (0.94-1.34)	1.07 (0.92-1.44)
	OBEC	1.16 (1.02-1.34)	1.38 (1.14-2.17)
	CBEO	2.98 (2.29-3.36)	2.82 (2.41-3.69)
	CBEC	3.85 (3.06-5.01)	3.50 (2.74-4.72)
	Tandem Right	3.92 (3.29-4.56)	3.71 (3.26-4.70)
	Tandem Left	3.80 (3.21-4.59)	4.05 (3.52-4.50)
Y Range (mm)	OBEO	1.98 (1.67-2.47)	2.26 (1.85-2.82)
	OBEC*	2.23 (1.92-2.71)	3.09 (2.82-3.97)
	CBEO	3.08 (2.19-3.43)	2.81 (2.12-3.36)
	CBEC*	3.11 (2.70-3.70)	3.71 (3.31-4.46)
	Tandem Right	4.00 (2.98-6.90)	3.87 (2.59-5.00)
	Tandem Left	3.54 (3.08-5.48)	4.40 (3.21-5.42)
Effective Area (mm^2)	OBEO	0.57 (0.37-0.65)	0.59 (0.42-0.77)
	OBEC*	0.64 (0.41-0.98)	1.04 (0.78-1.87)
	CBEO	1.81 (1.09-2.10)	1.48 (1.05-2.18)
	CBEC	1.97 (1.60-3.25)	2.52 (1.54-3.59)
	Tandem Right	3.52 (1.74-4.93)	2.81 (1.38-4.04)
	Tandem Left	2.10 (1.60-3.94)	3.16 (1.78-5.21)

Data are presented as the median (1st - 3rd quartile). *$p\leq0.01$ (Mann Whitney Test).
SD = Standard Deviation; OBEO = Opened Base, Eyes Open; OBEC = Opened Base, Eyes Closed; CBEO = Closed Base, Eyes Open; CBEC = Closed Base, Eyes Closed.

Weight, body mass index, waist circumference, fat percentage, and fat mass were positively and significantly correlated with the number of contacts needed to avoid falling during unilateral stance, but only the fat percentage and the fat mass were associated with the number of contacts during right and left unilateral stance. The greater responsiveness observed during left stance may be related to the greater number of individuals with right leg dominance (Table 1). Supporting the body for a one-minute period should be more difficult with the non-dominant leg than with the dominant leg. This correlation becomes stronger when the results for the non-dominant unilateral stance are analyzed (Table 3). When controlling body sway becomes more difficult, it becomes easier to detect differences due to other causes, such as adiposity.

When the entire sample was divided into two groups based on median fat mass, greater instability was observed in the High Fat Mass Group for some stabilometric variables when the subjects' eyes were closed, which is a situation in which visual feedback is eliminated and better integration of somatosensory and vestibular inputs are required to ensure adequate postural control. In addition to the results

Table 3 - Correlations observed during unilateral stance: Number of foot or hand contacts *vs.* body composition and general variables.

Variable	RUS	LUS	NDUS
Weight (kg)	0.17	0.30*	0.33*
Height (m)	-0.10	-0.02	0.02
BMI (kg/cm^2)	0.30	0.36*	0.37*
Age (years)	0.26	0.30	0.31*
Waist (cm)	0.22	0.42*	0.41*
Fat %	0.46*	0.43*	0.44*
Fat mass (kg)	0.31*	0.38*	0.40*
FFM (kg)	-0.03	0.16	0.19

The presented values are the Spearman Correlation Coefficients.
*$p<0.05$;
*$0.05<p<0.10$. BMI = Body Mass Index; Fat % = Fat percentage; FFM = Fat-free mass; RUS = right unilateral stance; LUS = left unilateral stance; NDUS = Non-dominant unilateral stance.

for effective area, the higher values for anterior-posterior standard deviation and range demonstrate that the women with higher fat mass scores oscillate their center-of-foot pressure more than the women with lower fat mass scores as predicted by our hypothesis. The observed differences were mainly in anterior-posterior direction, which was expected, due to the loss of ankle flexibility in elderly individuals. Furthermore, the lack of ankle flexibility influences anterior-posterior stability more than does lateral stability.[32]

Postural control differences in tandem positions were not observed. Considering that only 34 and 35 individuals (for the right and left conditions, respectively) successfully completed 60 seconds in this stance, the exclusion of subjects with poor performance could have influenced the final results. These trials were excluded when the hand support or foot adjustment added noise to the signal for the center-of-foot displacement. However, women with poor performance in tandem stances were not considered for analysis if these signals had been excluded, and only those with less body sway remained in the analysis. This decision could have influenced the power of the study to distinguish an association between adiposity and body sway. A study carried out in São Paulo, Brazil, determined that postural control in quiet standing may not influence the quality or pattern of movement during functional activity;[33] thus, tandem positions were expected to show greater differences than quiet stance trials.

The correlations of fat mass and waist circumference with unilateral stance behavior can be explained by the smaller range of the stability limit previously documented in obese individuals.[9] These correlations and the differences in certain stabilometric variables between the High and Low Fat Mass Groups attest to the relationship between adiposity and instability in the present elderly sample. Thus, it can be speculated that a higher quantity of fat mass may influence the localization and displacement of the center-of-foot pressure, altering stabilometric variables and causing the subject to make a greater number of hand and foot contacts to avoid falls during unilateral stance. After the sixth decade, it is well established that there is a reduction in total body mass, which is primarily influenced by the decrease in bone and muscle mass.[34] Furthermore, aging is associated with fat redistribution; visceral fat increases, whereas subcutaneous fat in other regions of the body (abdomen, thigh, calves) decreases.[22] These changes may disturb postural control.

Health professionals should be concerned with overweight and obese elderly individuals. Without specific intervention, aging will increase body fat, decreasing the level of total physical activity even further and increasing the accumulation of adipose tissue. In accordance with the reported results, this higher amount of fat mass can increase instability and disturb postural control in the elderly, which could lead to a greater number of falls. A focus on the prevention and treatment of obesity in elderly subjects delays the risk of metabolic complications, reduces the risk of falls and, consequently, enhances the quality of life of the elderly population. Because obesity occurs when energy intake consistently exceeds energy expenditure, interventions must emphasize nutrition reeducation and promote an adequate level of physical activity and a healthy lifestyle, as recommended by a multi-professional team, including physicians, physical therapists, psychologists, physical educators and dietitians. Regular evaluation of adiposity levels in elderly individuals should be adopted using such simple but reliable techniques as bioelectrical impedance and waist circumference measurements. Furthermore, balance and mobility tests must also be performed using stabilometry or other methods used in clinical practice, such as the Berg balance scale and timed up-and-go test.

It is important to emphasize that the results of the present study are limited to the selected population, which consists of a sample that was readily recruited from female participants in a university program for the elderly. Although the use of bioelectrical impedance to measure body composition is a limitation of this study, given that there are more accurate methods for assessing body fat levels, bioelectrical impedance is widely used in clinics and health promotion centers.

CONCLUSIONS

This study shows that there is an association between body adiposity and postural balance control in elderly women. The women with greater fat masses presented higher values for stabilometric variables and required a greater number of contacts to avoid falling, reflecting less efficient postural control.

REFERENCES

1. IBGE – Brazilian Institute of Geography and Statistics. Perfil dos Idosos Responsáveis pelos Domicílios no Brasil. Estudos & Pesquisas – Informação Demográfica e Socioeconômica. 2002;9.
2. Sanches GDS, Gazoni FM, Konishi RK, Guimarães HP, Vendrame LS, Lopes RD. Intensive care of postoperative patients in bariatric surgery. Rev bras ter intensiva. 2007;19:205-9, doi: 10.1590/S0103-507X2007000200011.
3. Ogden CL, Carroll MD, Curtin LR, McDowell MA, Tabak CJ, Flegal KM. Prevalence of Overweight and Obesity in the United States, 1999-2004. JAMA. 2006;295:1549-55, doi: 10.1001/jama.295.13.1549.
4. West NA, Haan MN. Body Adiposity in Late Life and Risk of Dementia or Cognitive Impairment in a Longitudinal Community-Based Study. J Gerontol A Biol Sci Med Sci. 2009;64:103-9, doi: 10.1093/gerona/gln006.
5. Chumlea WC, Guo SS, Kuczmarski RJ, Flegal KM, Johnson CL, Heymsfield SB, et al. Body composition estimates from NHANES III bioelectrical impedance data. Int J Obes (Lond). 2002;26:1596–609, doi: 10.1038/sj.ijo.0802167.
6. Wu CH, Heshka S, Wang J, Pierson Jr RN, Heymsfield SB, Laferrère B, et al. Truncal fat in relation to total body fat: influences of age, sex, ethnicity and fatness. Int J Obes (Lond). 2007;31:1384-91, doi: 10.1038/sj.ijo.0803624.
7. Stenholm S, Alley D, Bandinelli S, Griswold ME, Koskinen S, Rantanen T, et al. The effect of obesity combined with low muscle strength on decline in mobility in older persons: results from the InCHIANTI Study. Int J Obes (Lond). 2009;33:635–44, doi: 10.1038/ijo.2009.62.
8. Greve J, Alonso A, Bordini ACPG, Camanho Gl. Correlation Between Body Mass Index and Postural Balance. Clinics. 2007;62:717-20, doi: 10.1590/S1807-59322007000600010.
9. Blaszczyk JW, Cieslinska-Swider J, Plewa M, Zahorska-Markiewicz B, Markiewicz. A Effects of excessive body weight on postural control. J Biomech. 2009;42:1295-300, doi: 10.1016/j.jbiomech.2009.03.006.
10. WHO - World Health Organization. Obesity – Preventing and Managing the Global Epidemic. 1998;1-158.
11. Reach CR, Cordeiro BA, Petroski EL, Vasconcelos FAG. Validation of Bioelectrical Impedance for the Prediction of Fat-free Mass in Brazilian Elderly Subjects. Arq Bras Endocrinol Metab. 2008;52:1163-71, doi: 10.1590/S0004-27302008000700013.
12. Kyle UG, Bosaeus I, De Lorenzo AD, Deurenberg P, Elia M, Gómez JM, et al. Bioelectrical impedance analysis - part I: review of principles and methods. Clin Nutr. 2004;23:1226-43, doi: 10.1016/j.clnu.2004.06.004.
13. Deurenberg P, Deurenberg-Yap M. Validation of skinfold thickness and hand-held impedance measurements for estimation of body fat percentage among Singaporean Chinese, Malay and Indian subjects. Asia Pacific J Clin Nutr. 2002;11:1-7, doi: 10.1046/j.1440-6047.2002.00258.x.
14. Wang JA, Thornton JC, Bari S, Williamson B, Gallagher D, Heymsfield SB, et al. Comparisions of Waist circumferences measured at 4 sites. Am J Clin Nutr. 2003;77:379-84.

15. Shields M, Tremblay MS, Laviolette M, Craig CL, Janssen I, Gorber SC. Fitness of Canadian adults: Results from the 2007-2009 Canadian Health Measures Survey. Health Rep. 2010;21:21-35.
16. Mainenti MRM, Oliveira LF, Lima MAMT, Nadal J. Stabilometric signal analysis in tests with sound stimuli. Exp Brain Res. 2007;181:229-36, doi: 10.1007/s00221-007-0921-4.
17. Cavalheiro GL, Almeida MFS, Pereira AA, Andrade AO. Study of age-related changes in postural control during quiet standing through Linear Discriminant Analysis. Biomed Eng Online. 2009;8:35, doi: 10.1186/1475-925X-8-35.
18. Viljanen A, Kaprio J, Pyykkö L, Sorri M, Pajala S, Kauppinen M, et al. Hearing as a Predictor of Falls and Postural Balance in Older Female Twins. J Gerontol A Biol Sci Med Sci. 2009;64A:312-7, doi: 10.1093/gerona/gln015.
19. Schrager MA, Kelly VE, Price R, Ferrucci L, Shumway-Cook A. The Effects of Age on Medio-lateral Stability during Normal and Narrow Base Walking. Gait Posture. 2008;28:466–71, doi: 10.1016/j.gaitpost.2008.02.009.
20. Abrahamová D, Hlavačka E. Age-Related Changes of Human Balance during Quiet Stance. Physiol Res. 2008;57:957-64.
21. Ruwer SL, Rossi AG, Simon LF. Balance in the elderly. Rev Bras Otorrinolaringol. 2005;71:298-303, doi: 10.1590/S0034-72992005000300006.
22. Zamboni M, Mazzali G, Zoico E, Harris TB, Meigs JB, Di Francesco V, et al. Health consequences of obesity in the elderly: a review of four unresolved questions. Int J Obesity (Lond). 2005;29:1011–29, doi: 10.1038/sj.ijo.0803005.
23. Kyle UG, Genton L, Karsegard L, Slosman DO, Pichard C. Single prediction equation for bioelectrical impedance analysis in adults aged 20–94 years. Nutrition. 2001;17:248-53, doi: 10.1016/S0899-9007(00)00553-0.
24. Genton LC, Karsegard VL, Kyle UG, Hans DB, Michel JP, Pichard C. Comparison of four bioelectrical impedance analysis formulas in healthy elderly adults. Gerontology. 2001;47:315–23, doi: 10.1159/000052821.
25. ISAK (International Society for the Advancement of Kinanthropometry). International Standards for Anthropometric Assessment. Australia: ISAK, 2001.
26. Medronho RA, Bloch KV, Luiz RR, Werneck GL. Epidemiologia. 2 ed. São Paulo: Atheneu, 2008.
27. Barbosa AR, Souza JMP, Lebrão ML, Marucci MFN. Nutritional Status and Physical Performance of Elderly in the City of São Paulo. Rev Assoc Med Bras. 2007;53:75-9, doi: 10.1590/S0104-42302007000100024.
28. Romero-Corral A, Somers VK, Sierra-Johnson J, Thomas RJ, Bailey KR, Collazo-Clavell ML, et al. Accuracy of Body Mass Index to Diagnose Obesity In the US Adult Population. Int J Obes (Lond). 2008;32:959-66, doi: 10.1038/ijo.2008.11.
29. Winter DA, Patla AE, Prince F, Ishac M, Gielo-Perczak K. Stiffness Control of Balance in Quiet Standing. J Neurophysiol. 1998;80:1211-21.
30. Deurenberg P, Andreoli A, Borg P, Kukkonen-Harjula K, de Lorenzo A, van Marken WD, et al. The validity of predicted body fat percentage from body mass index and from impedance in samples of five European populations. Eur J Clin Nutr. 2001;55:973–9, doi: 10.1038/sj.ejcn.1601254.
31. Sun SS, Chumlea WC, Heymsfield SB, Lukaski HC, Schoeller D, Friedl K, et al. Development of bioelectrical impedance analysis prediction equations for body composition with use of a multicomponent model for use in epidemiologic surveys. Am J Clin Nutr. 2003;77:331-40.
32. Shumway-Cook A, Woollacott M. Motor control: Translating Research into Clinical Practice. USA: Lippincott Williams & Wilkins, 2007.
33. Moya GBL, Siqueira CM, Caffaro RR, Fu C, Tanaka C. Can quiet standing posture predict compensatory postural adjustment? Clinics. 2009;64:791-6, doi: 10.1590/S1807-59322009000800014.
34. McArdle WD, Katch FI, Katch VL. Exercise Physiology – Energy, Nutrition and Human Performance. 6th ed. Philadelphia: Lippincot Williams & Wilkins. 2007;868-966.