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Effects of obesity on postural balance and occurrence of falls in asymptomatic adults

Efeitos da obesidade no equilíbrio postural e ocorrência de quedas em adultos assintomáticos

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Abstract

Introduction: Previous studies suggested that body weight is a strong predictor for postural balance. High body mass index (BMI) presented an association with increased postural sway. However, it seems controversial since studies reported no difference between obese and control group regarding the position of the center of pressure in static postural balance (PB). Also, there is a lack of investigations about the impact of obesity on PB, free of the confound effect of cardiometabolic risk. **Objective:** The aim of this study was to evaluate the effects of obesity in static PB and occurrence of falls in asymptomatic adults and older adults over 40 years old. **Method:** The PB of 624 subjects divided into quartiles for BMI, waist-to-hip ratio, waist-to-height and fat body mass as percentage (%FBM) was assessed with and without vision using a force platform. An MANOVA was used to determine if there were differences between quartiles and a logistic regression analysis adjusted for confounders variables were applied to determine the obesity role in the occurrence of falls. **Results:** We found weak to moderate bivariate correlations between obesity and static PB, which

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became non-significant after adjustment. We found significant differences between first and fourth quartiles, especially using %FBM. Obesity was not related to the occurrence of falls since the odds ratio values became non-significant for all the indices of obesity after adjustment. **Conclusion:** Obesity presents little influence on maintaining static PB and seems not to determine the occurrence of falls among subjects over 40 years old.

Keywords*:* Falls. Postural Balance. Obesity.

Resumo

Introdução: *Estudos prévios sugerem que o peso corporal é forte preditor do equilíbrio postural. Índice de Massa Corporal (IMC) apresenta associação com oscilação corporal aumentada. Contudo, isto é controverso já que estudos reportaram que não há diferença entre obesos e grupo controle em relação ao deslocamento do centro de pressão no equilíbrio postural (EP) estático. Além disso, a literatura é escassa sobre o impacto da obesidade sem o efeito confundidor do risco cardiometabólico.* ***Objetivo:*** *Avaliar os efeitos da obesidade no EP estático e na ocorrência de quedas em adultos assintomáticos acima de 40 anos.* ***Método:*** *O EP estático dos 624 indivíduos divididos segundo os quartis de IMC, relação cintura-quadril e cintura-altura e gordura corporal em porcentagem (% GC) foi avaliado com olhos abertos e fechados usando uma plataforma de força. As diferenças entre os quartis foram determinadas por meio de uma MANOVA e o papel da obesidade na ocorrência de quedas foi analisado por meio de regressão logística ajustada pelos principais confundidores.* ***Resultados:*** *Obtivemos correlações bivariadas fracas a moderadas entre a obesidade e o EP estático, que, após ajuste, não foram estatisticamente significativas. Observamos diferenças significativas entre primeiro e quarto quartis, sobretudo para quartis de %GC. A obesidade não se associou à ocorrência de quedas já que os valores de odds ratio perderam significância para todos os índices d e obesidade após o ajuste pelos confundidores.* ***Conclusão:*** *Obesidade apresenta pouca ou nenhuma influência na manutenção do EP estático e parece não determinar a ocorrência de quedas em indivíduos acima de 40 anos.*

Palavras-chave: *Quedas. Equilíbrio Postural. Obesidade.*

Introduction

Postural instability is tightly related to the occurrence of falls [1, 2]. Currently, it is one of the largest public health problems [3] that cause increasing rates of mortality and morbidity, also leads to immobility situations, loss of independence and hospitalization [4].

Among the numerous factors that could influence the maintenance of postural balance (PB), body weight is suggested to be a strong predictor [5] and being obese is considered a potential contributing factor for falling [6, 7]. Therefore, high body mass index (BMI) has an association with increased postural sway in obese [6, 8], mainly in the medial-lateral (ML) direction for men and anteroposterior (AP) for women [8–10], and occurrence of falls in adults [11]. However, some studies reported no difference between obese and control group regarding the position of the center of pressure (COP) in static PB [12, 13] and the dynamic gait stability [14]. Although these previous findings suggest that body weight is responsible for more than 50% of the variance of COP speed [5], it is not reasonable just to consider this anthropometric variable for explaining the PB in obesity. According to a recent study, the waist circumference presented a strongest association with stabilometric parameters and fall-related outcomes when compared to other anthropometric measurements [15], but other study showed that fat body mass (FBM) is associated to poor balance [16]. Since body mass is insufficient to represent the impact of obesity on static PB, the best anthropometric and body composition variable able to represent the above-mentioned relationship remains to be established.

Obesity is commonly associated with cardiometabolic comorbidities, lower physical fitness and reduced physical activity [17] and, to our knowledge, there is a lack of investigations about the impact of obesity on PB, free of the confound effect of cardiometabolic risk. Since falling can be determined by the interaction between chronic predisposing diseases and impairments [18], there is a need to consider these other variables to clarify the association between static PB and obesity.

We hypothesized that obesity has little or no influence on PB when considering the confound effect of cardiometabolic comorbidities and physical fitness. Therefore, the aim of this study was to evaluate the effects of obesity on static PB in asymptomatic adults by using and comparing anthropometric measures and fat body mass (FBM). Secondarily, the study was designed to evaluate the association of obesity with the occurrence of falls in a subsample of middle-aged and older adults.

Method

Participants

We conducted a cross-sectional study with eligible participants from Epidemiological Study on Human Movement (EPIMOV Study). Briefly, the EPIMOV Study is an epidemiological study with the main objective of determine the longitudinal association shown by sedentary behavior and physical inactivity related to development of hypokinetic diseases [19]. The Research Ethics Committee of human beings approved the EPIMOV study (# 186.796). In addition, all participants provided written informed consent.

The volunteers were recruited by announcements in social medias, in regional universities, in magazines and local journals. The EPIMOV Study exclusion criteria are previous diagnosis of cardiovascular, respiratory or musculoskeletal disease and/or any health problem that might interfere the ability to undertake physical exercise. All EPIMOV Study's participants were eligible for this study. For the present study, we selected those with ≥ 40 years.

Since the proportion of fallers among middle-aged and older adults is similar and the rate of falls and fall-related injuries increases from 25 years and above [2], it is reasonable to investigate the determinants of postural balance in middle-aged subjects.

Clinical evaluation

Before starting the evaluation, we questioned the volunteers about previous health problems, regular use of medication and risk factors for cardiovascular diseases, such as age, family history, smoking, hypertension, dyslipidemia, and diabetes mellitus. Then, they answered the Physical Activity Readiness Questionnaire for identifying possible contraindications of performing exercise [20].

Anthropometric and body composition

We collected height (m) and body mass (kg) by using a digital balance with a stadiometer (Toledo®, São Paulo, Brazil). Circumferences of hip and waist were measured according to standardized techniques [21]. Then, we calculated BMI (kg/m^2), waist-to-hip ratio and waist-to-height ratio.

We assessed body composition by using bioelectrical impedance (310e BIODYNAMICS, Detroit, EUA) at ambient temperature. The impedance and the reactance were collected from the subject in the supine position with arms and legs in 30º and 45º of abduction, as described previously [22, 23]. Using the equation developed for healthy subjects [24], we calculated lean body mass (LBM) and FBM. LBM and FBM were expressed as percentage and absolute value. We instructed volunteers to avoid ingesting any liquid or food for prior 4 hours and avoid practicing physical exercises for at least 12 hours before the test.

Cardiorespiratory fitness

We performed a cardiopulmonary exercise testing (CEPT) on a treadmill (ATL, Inbrasport, Porto Alegre, Brazil) using a ramp protocol with individualized increases in velocity and inclination until exhaustion [25]. Oxygen uptake (V'O2), carbon dioxide production (V'CO2), and minute ventilation (V'E) were monitored throughout the test using a gas analyzer (Quark PFT, Cosmed, Pavona di Albano, Italy). The heart rate (HR) was continuously monitored during the CPET by means of a 12 lead ECG. The average value of the V'O2 (mL/min/kg) during the last 15 s of the CPET was representative of the peak V'O2 (i.e., cardiorespiratory fitness) [25].

Physical activity level

We assessed the level of physical activity in daily life (PADL) using triaxial accelerometers (ActiGraph, MTI, Pensacola, FL) previously validated [26, 27]. All participants were carefully instructed regarding the use of the aforementioned devices. They performed the evaluation during a week after the first-day test in this study. We analyzed only the data of participants who used the accelerometer for at least four valid days (e.g., 10 wakening hours of monitoring). The minimum PADL was considered as 30 minutes daily of MVPA for at least 5 days per week, as recommended [28]. Participants who did not reach this level were considered as physically inactive.

Postural balance

We evaluated PB using the kinetic displacement of the COP on a force platform (BIOMEC 400, EMGSystem, Brazil) [29, 30]. The frequency of data acquisition was recorded at 100 Hz and filtered using a low-pass cut-off of 0.5 Hz. Participants were evaluated with arms held alongside the body in bipedal stance (BS) and in semi-tandem stance (ST) for 30 seconds in each test. First, with eyes fixating a reference point located at eyes level (1 m in front of them) and, then, with eyes closed. Volunteers performed one trial for each condition. Body sway was measured along AP and ML directions. We recorded average amplitude, median frequency, and COP area for further analysis. Average amplitude (cm) was obtained through variance values of body sway on directions AP and ML. The area of the ellipse was obtained by covering the COP sway trajectory. The amplitude of displacement is a reliable parameter and widely used to evaluate postural deficits, especially in the ML direction [29].

Muscle function

We evaluated muscle function through isokinetic dynamometry (Biodex, Lumex Inc., Ronkonkoma, NY, EUA) as previous described [31]. In seated position, the upper body and the assessed lower limb were completely fixed by strips. We aligned the mechanical axis of rotation of the device to the rotational axis of the assessed joint. After a trial session, we assessed the peak torque of knee extension (PT, Nm) by five movements at 60º/s. The greater value was selected for further analysis. We applied these tests to quadriceps muscle under vehement verbal encouragement.

History of falls

Participants were inquired about the occurrence of falls in the 12 months prior to the study. The participants answered two questions: "Did you fall in the last 12 months?". If the answer was yes, we also inquired how many falls did they suffer in this period. They were stratified as fallers, who had one or more falls within 12 months prior to the study, and non-fallers, who had none fall within the period. Fall was defined as any unplanned and unexpected event that results in body contact to the surface [3].

Statistical Analysis

The statistical analysis was performed using SPSS, version 23 (SPSS Inc., Chicago, IL, EUA). We present data as means ± SD and 95% confidence interval. Initially, we evaluated the Pearson or Spearman coefficient of correlations for testing the bivariate relationship between indices of obesity (BMI, FBM, waist-to-hip ratio, and waist-to-height ratio) and the PB variables. Then, we performed several multiple linear regression models to confirm whether or not the indices of obesity are independent predictors of PB.

For identifying the best index of obesity able to predict PB as well as for comparing the influence of the severity of obesity on PB, we stratified the whole sample according to the quartiles of BMI, waist-to-hip ratio, waist-to-height ratio and percentage of FBM. We compared all the force platform variables using the MANOVA analysis, after normalization of the data using logarithms. We presented the significant differences by means of box plots.

As for the associations with the occurrence of falls, we dichotomized the participants according to the medians of the above-mentioned indices of obesity. Lastly, we carried out four multiple logistic regressions using the history of falls (0 = no falls, 1 = 1 or more falls) as the outcome and the categorized indices of obesity as the main predictors.

All the multivariate analysis were adjusted for age (years), sex, peak V'O2 (ml/min/kg), LBM (kg), PT (Nm) and the presence of diabetes, dyslipidemia, physical inactivity (assessed by triaxial accelerometers), hypertension, and smoking. The sample size was estimated based on the number of variables included in the multivariate model and the minimum number of observations required, indicating at least 165 subjects for elaborating a model containing these variables. The level of statistical significance was set at $p < 0.05$.

Results

624 participants (aged 18 to 82 years, 260 men) from EPIMOV Study were considered eligible. The sample was composed mainly by women with prevalence of risk factors for cardiovascular diseases as follows: hypertension (19.9%), diabetes (9.3%), dyslipidemia (30.9%), smoking (11%) and physical inactivity (27%).

For women, the defined quartiles of BMI, waist-to-hip ratio, waist-to-height ratio and percentage of FBM were, respectively, as follows: 23.72, 28.60 and 34.13 kg/m2; 0.48, 0.56 and 0.64; 0.77, 0.83 and 0.89; and 29.6, 36.6 and 41.3%. And for men, the quartiles were 24.25, 27.25 and 30.47 kg/m2 for BMI, 0.47, 0.52 and 0.59 for waist-to-hip ratio, 0.84, 0.89 and 0.96 for waist-to-height ratio, and 17.5, 23.4 and 28.1% for FBM.

As expected, the fourth quartile of BMI has the greater values for all variables, except for PT and peak V'O2, indicating lower physical fitness among severely obese subjects (Table 1).

The logistic regression analysis showed that obesity was not related to the occurrence of falls since the odds ratio values became non-significant for all these indices of obesity after adjustment for the main confounders (Table 2).

We found weak to moderate bivariate correlations between the indices of obesity and the static PB. Most of then became non-significant after multiple regression analysis adjusted for the main confounders as can be seen in the Table 3.

We observed some significant differences between first and fourth quartiles of the indices of obesity, especially using %FBM (Figure 1) and for body sway on ML direction (Table 4).

Table 1 - General characteristics of the studied sample stratified according to the quartiles of the body mass index

	Quartile 1 N = 156	Quartile 2 N = 156	Quartile 3 N = 157	Quartile 4 N = 155
Age (years)	38 ± 15	42 ± 15[a]	50 ± 13[ab]	51 ± 12[ab]
Males/females	62/94	68/88	65/92	65/90
Weight (kg)	58.3 ± 7.8	70.8 ± 9.0[a]	80.5 ± 10.5[ab]	97.7 ± 14.3[abc]
Height (m)	1.63 ± 0.09	1.64 ± 0.09	1.62 ± 0.10	1.61 ± 0.09
Body mass index (kg/m2)	21.8 ± 1.6	25.9 ± 1.1[a]	30.2 ± 1.45[ab]	37.6 ± 4.4[abc]
Waist (cm)	73.4 ± 7.0	84.3 ± 7.1[a]	94.9 ± 9.1[ab]	109.8 ± 11.5[abc]
Hip (cm)	92.3 ± 4.8	99.9 ± 5.1[a]	105.9 ± 7.4[ab]	122.0 ± 10.8[abc]
Waist-to-hip ratio	0.80 ± 0.08	0.85 ± 0.08[a]	0.90 ± 0.09[ab]	0.90 ± 0.08[ab]
Waist-to-height ratio	0.45 ± 0.05	0.51 ± 0.04[a]	0.58 ± 0.06[ab]	0.68 ± 0.08[abc]
Lean body mass (kg)	44.7 ± 9.2	52.1 ± 10.4[a]	54.0 ± 11.2[a]	57.8 ± 10.4[abc]
Lean body mass (%)	75.9 ± 7.1[bcd]	72.6 ± 6.9[cd]	66.5 ± 7.4[d]	58.7 ± 6.8
Fat body mass (kg)	13.6 ± 3.6	19.4 ± 5.6[b]	26.6 ± 5.5[ab]	40.2 ± 8.4[abc]
Fat body mass (%)	23.8	27.4 ± 7.0[a]	33.3[ab]	40.9 ± 5.3[abc]
Peak torque of knee extension (NM)	127 ± 51	140 ± 55	132 ± 61	123 ± 49
Peak oxygen uptake (mL/min/kg)	36.5 ± 10.7	28.9 ± 10.5[a]	26.8 ± 8.6[ab]	20.8 ± 5.1[abc]
Number of fallers (%)	6 (3.8)	9 (5.8)	17 (10.8)	28 (18.1)[ab]

Note: [a]p < 0.05 vs. quartile 1; [b]p < 0.05 vs. quartile 2 ; [c]p < 0.05 vs. quartile 3 ; [d]p < 0.05 vs. quartile 4.

Table 2 – Associations between severity of obesity and the occurrence of falls in the studied sample over the age of 40 years (n = 387)

	Unadjusted odds ratios and 95% confidence intervals			Adjusted odds ratios and 95% confidence intervals		
		95% confidence interval			95% confidence interval	
	OR	Lower limit	Upper limit	OR	Lower limit	Upper limit
Body mass index	3.75*	2.13	6.60	1.43	0.52	3.90
Fat body mass	4.13*	2.19	7.81	1.47	0.54	4.04
Waist-to-hip ratio	2.27*	1.23	4.17	1.57	0.59	4.19
Waist-to-height ratio	3.41*	1.40	8.25	2.09	0.64	6.80

Note: *p < 0.05. Predictors were binned according to the median values.

Table 3 - Results of bivariate and multiple regression models: correlations between indexes of obesity and postural balance in bipedal and semi-tandem stance with eyes open and closed

	Fat body mass (%)		Body mass index (km/m2)		Waist-to-hip ratio		Waist-to-height ratio	
	Unadjusted coefficient	Adjusted coefficient	Unadjusted coefficient	Adjusted coefficient	Unadjusted coefficient	Adjusted coefficient	Unadjusted coefficient	Adjusted coefficient
Bipedal stance with eyes open								
Average Amplitude Anteroposterior (cm)	0.010*	0.005	0.020*	0.014	0.648	-0.271	1.046*	0.836
Average Amplitude Medial-Lateral (cm)	0.000	0.003	0.007	0.004	1.082	0.867	0.602	-0.655
Median Frequency Anteroposterior (cm)	0.001	-0.001	0.000	-0.003	-0.024	-0.176	0.087	-0.194
Media Frequency Medial-Lateral (cm)	-0.003*	-0.006	-0.005*	-0.007*	-0.225*	-0.464*	-0.308*	-0.486
Center of Pressure Area (cm)	0.020	-0.027	0.024	-0.009	0.697	-1,787	1.934	-1.434
Bipedal stance with eyes closed								
Average Amplitude Anteroposterior (cm)	0.046*	0.026*	0.015*	0.041*	4.564	1.517	4.413*	2.891*
Average Amplitude Medial-Lateral (cm)	0.011*	0.007	0.016*	0.014	0.444	0.089	1.025*	0.989
Median Frequency Anteroposterior (cm)	0.000	-0.003	-0.003	-0.009	-0.572	-0.325	-0.332	-0.520
Media Frequency Medial-Lateral (cm)	-0.004*	-0.003	-0.005*	-0.004	-0.096	-0.117	-0.253*	-0.294
Center of Pressure Area (cm)	0.053	0.133	0.099*	0.115	2.530	-1.590	5.125	10.231
Semi-tandem stance with eyes open								
Average Amplitude Anteroposterior (cm)	-0.001	0.013	0.001	0.002	0.944	0.818	0.541	0.066
Average Amplitude Medial-Lateral (cm)	0.007	0.011	0.004	-0.002	0.344	0.355	0.406	-0.422
Median Frequency Anteroposterior (cm)	-0.002*	-0.008*	-0.004*	-0.008*	0.070	-0.299	-0.119	-0.505
Media Frequency Medial-Lateral (cm)	0.000	-0.003	0.000	-0.001	0.119	-0.110	0.109	0.023
Center of Pressure Area (cm)	0.013	0.022	0.012	-0.013	0.623	0.292	1.267	-1.453
Semi-tandem stance with eyes closed								
Average Amplitude Anteroposterior (cm)	0.021	0.043	0.004	-0.010	-2.212	0.021	-1.042	-0.977
Average Amplitude Medial-Lateral (cm)	0.026*	0.038*	0.044*	0.029	2.768*	1.306	2.385*	0.994
Median Frequency Anteroposterior (cm)	0.003	-0.022	-0.004	-0.013	-0.156	0.542	-0.314	-1.774
Media Frequency Medial-Lateral (cm)	0.004	-0.011	-0.001	-0.006	-0.124	0.533	-0.42	-0.734
Center of Pressure Area (cm)	0.097*	0.163*	0.167*	0.125*	10.252*	5.999	9.469*	5.354

Note: *$p < 0.05$. Models adjusted by: age (years), sex, peak V'O2 (ml/min/kg), LBM (Kg), peak torque of knee extension (Nm) and the presence of diabetes, dyslipidemia, physical inactivity, hypertension, and smoking.

Table 4 – Data from Postural Balance Assessment of the studied sample stratified according to the quartiles of the body mass index, waist-to-hip ratio and waist-to-height ratio

	Body mass index (kg/m2)				Waist-to-hip ratio				Waist-to-height ratio			
	Quartile 1 N = 156	Quartile 2 N = 155	Quartile 3 N = 157	Quartile 4 N = 155	Quartile 1 N = 104	Quartile 2 N = 154	Quartile 3 N = 200	Quartile 4 N = 165	Quartile 1 N = 138	Quartile 2 N = 161	Quartile 3 N = 159	Quartile 4 N = 165
Bipedal stance with eyes open												
Average Amplitude Anteroposterior (cm)	1.96(1.82-2.09)	1.96(1.77-2.14)	2.12(1.96-2.27)	2.26(2.10-2.42)	2.06(1.88-2.23)	1.95(1.81-2.10)	2.07(1,91-2.23)	2.20(2.04-2.36)	1.94(1.81-2.07)	2.04(1.86-2.23)	1,97(1.84-2.10)	2,31(2.14-2.49)
Average Amplitude Medial-Lateral (cm)	1.17(1.04-1.31)	1.20(0.98-1.41)	1.41(1.13-1.70)	1.16(0.98-1.34)	1.17(0.95-1.35)	1.15(1.01-1.28)	1.18(1,00-1.36)	1.43(1.14-1.72)	1.11(0.98-1.24)	1.28(1.06-1.50)	1,06(0.96-1.16)	1,46(1.16-0.77)[c]
Median Frequency Anteroposterior (cm)	0.26(0.24-0.27)	0.29(0.23-0.35)	0.25(0.23-0.27)	0.28(0.22-0.34)	0.29(0.20-0.37)	0.25(0.23-0.27)	0.28(0,23-0.33)	0.26(0.24-0.28)	0.26(0.24-0.27)	0.27(0.22-0.33)	0,27(0.24-0.29)	0,28(0.22-0.34)
Media Frequency Medial-Lateral (cm)	0.46(0.43-0.49)	0.45(0.38-0.52)	0.40(0.38-0.43)	0.38(0.32-0.45)	0.49(0.38-0.59)	0.41(0.38-0.44)	0.43(0,38-0.49)	0.38(0.36-0.41)[a]	0.47(0.44-0.51)	0.43(0.37-0.50)	0,41(0.38-0.43)	0,39(0.32-0.45)
Center of Pressure Area (cm)	1.73(1.17-2.28)	1.56(1.18-1.93)	2.21(0.94-3.47)	1.86(1.36-2.36)	1.61(1.20-2.02)	1.76(1.19-2.33)	1.66(1,23-2.09)	2.27(1.07-3.48)	1.66(1.06-2.27)	1.68(1.30-2.06)	1,45(1.20-1.69)	2,52(1.25-3.79)
Bipedal stance with eyes closed												
Average Amplitude Anteroposterior (cm)	2.89(1.35-4.43)	2.14(2.02-2.25)	3.72(1.25-6.19)	2.80(2.62-2.99)	2.11(1.96-2.25)	2.15(1.99-2.32)	3.02(1.82-4.22)	3.91(1.57-6.26)	2.02(1.90-2.14)	2.95(1.46-4.44)	3,60(1.17-6.04)	2,87(2.64-3.10)
Average Amplitude Medial-Lateral (cm)	0.99(0.91-1.07)	0.94(0.87-1.02)	1.04(0.93-1.15)	1.18(1.01-1.35)	1.01(0.91-1.11)	1.02(0.91-1.14)	1.01(0.90-1.13)	1.10(0.99-1.22)	0.97(0.88-1.05)	0.99(0.92-1.07)	1,00(0.89-1.10)	1,19(1.03-1.35)
Median Frequency Anteroposterior (cm)	0.29(0.27-0.30)	0.51(0.09-0.93)	0.31(0.29-0.34)	0.33(0.27-0.39)	0.59(0.03-1.21)	0.29(0.27-0.32)	0.33(0.28-0.37)	0.31(0.29-0.34)	0.53(0.06-1.00)	0.29(0.27-0.31)	0,30(0.28-0.32)	0,34(0.28-0.39)
Media Frequency Medial-Lateral (cm)	0.50(0.47-0.53)	0.49(0.46-0.52)	0.45(0.42-0.47)	0.42(0.37-0.48)	0.46(0.42-0.50)	0.48(0.45-0.51)	0.48(0.43-0.53)	0.43(0.41-0.46)	0.51(0.47-0.54)	0.48(0.45-0.51)	0,44(0.42-0.47)	0,44(0.38-0.49)
Center of Pressure Area (cm)	1.40(1.10-1.70)	1.23(1.09-1.38)	2.84(0.74-4.94)	2.64(1.71-3.57)	1.32(1.13-1.52)	1.75(0.95-2.55)	2.46(0.83-4.09)	2.22(1.592.84)	1.20(1.04-1.37)	1.44(1.16-1.73)	2,80(0.69-4.91)	2,55(1.77-3.33)
Semi-tandem stance with eyes open												
Average Amplitude Anteroposterior (cm)	1.88(1.72-2.04)	1.90(1.74-2.06)	2.15(1.87-2.43)	1.88(1.73-2.03)	2.00(1.71-2.29)	1.82(1.66-1.97)	1.93(1.80-2.06)	2.08(1.84-2.32)	1.80(1.67-1.93)	1.98(1.76-2.19)	1.96(1.80-2.11)	2.06(1.82-2.29)
Average Amplitude Medial-Lateral (cm)	2.67(2.45-2.90)	2.66(2.53-2.79)	2.89(2.63-3.15)	2.72(2.2-2.83)	2.82(2.47-3.18)	2.66(2.43-2.88)	2.69(2.58-2.80)	2.81(2.67-2.95)	2.63(2.39-2.88)	2.71(2.46-2.95)	2.76(2.64-2.89)	2.83(2.69-2.96)[a]
Median Frequency Anteroposterior (cm)	0.61(0.56-0.67)	0.61(0.57-0.65)	0.58(0.54-0.62)	0.53(0.50-0.56)	0.56(0.49-0.63)	0.57(0.53-0.60)	0.62(0.58-0.65)	0.58(0.54-0.62)	0.59(0.54-0.65)	0.59(0.54-0.63)	0.60(0.56-0.64)	0.55(0.52-0.59)
Media Frequency Medial-Lateral (cm)	0.35(0.33-0.38)	0.37(0.34-0.39)	0.39(0.36-0.42)	0.36(0.33-0.39)[c]	0.34(0.32-0.37)	0.36(0.33-0.38)	0.38(0.35-0.40)	0.38(0.36-0.41)	0.36(0.33-0.38)	0.36(0.34-0.38)	0.38(0.36-0.41)	0.37(0.34-0.40)[ac]
Center of Pressure Area (cm)	3.11(2.54-3.68)	3.01(2.68-3.35)	3.86(2.90-4.83)	3.14(2.81-3.46)	3.59(2.44-4.74)	3.01(2.45-3.56)	3.11(2.81-3.40)	3.56(2.92-4.21)	2.84(2.38-3.31)	3.46(2.63-4.29)	3.27(2.89-3.65)	3.49(2.87-4.11)
Semi-tandem stance with eyes closed												
Average Amplitude Anteroposterior (cm)	2.73(2.40-3.06)	4.33(1.57-7.08)[a]	3.41(2.98-3.83)	3.15(2.79-3.52)	4.73(0.63-8.83)	2.93(2.53-3.33)	3.15(2.81-3.50)	3.31(2.88-3.73)	4.12(1.04-7.20)	2.99(2.59-3.40)	3.27(2.84-3.70)	3.33(2.93-3.73)
Average Amplitude Medial-Lateral (cm)	4.39(4.16-4.62)	4.79(4.47-5.12)	5.07(4.73-5.41)	5.03(4.73-5.32)	4.27(4.06-4.47)	4.67(4.38-4.96)	5.05(4.78-5.33)	5.04(4.69-5.38)	4.25(4.07-4.42)	4.82(4.48-5.15)	5.02(4.71-5.32)	5.12(4.80-5.43)
Median Frequency Anteroposterior (cm)	0.70(0.66-0.74)	0.69(0.63-0.74)	1.25(0.16-2.33)[a]	0.62(0.58-0.67)[a]	0.62(0.57-0.66)	1.25(0.14-2.36)	0.66(0.63-0.70)	0.72(0.65-0.78)	0.66(0.62-0.70)	1.24(0.18-2.30)	0.66(0.62-0.71)	0.68(0.62-0.74)
Media Frequency Medial-Lateral (cm)	0.38(0.36-0.40)	0.38(0.33-0.43)	0.74(0.08-1.41)	0.37(0.32-0.42)	0.37(0.34-0.39)	0.73(0.05-1.41)	0.35(0.33-0.37)	0.44(0.36-0.51)	0.36(0.34-0.38)	0.73(0.08-1.38)	0.36(0.33-0.39)	0.41(0.33-0.48)
Center of Pressure Area (cm)	6.55(5.67-7.44)	7.52(6.49-8.55)	9.15(7.95-10.3)	8.68(7.50-9.86)	6.57(5.70-7.43)	7.16(6.18-8.14)	8.45(7.51-9.39)	9.06(7.73-0.39)	5.98(5.41-6.55)	7.66(6.57-8.76)	8.52(7.49-9.55)[a]	9.43(8.10-0.76)[ac]

Note: ap < 0.05 vs. quartile 1. bp < 0.05 vs. quartile 2. cp < 0.05 vs. quartile 3. dp < 0.05 vs. quartile 4. Data are presented as median (interquartile range).

Discussion

We found in the present study only a little influence on the severity of the obesity on the PB. However, these changes do not seem to be an important feature for increasing occurrence of falls among subjects over 40 years old.

Hue et al. [5] showed that the body weight is a strong predictor of PB using a stepwise multiple regression analysis adjusted for height, foot length, and age. Nevertheless, only 59 subjects were enrolled (BMI = 35.2 ± 11.7 kg/m^2 and age = 40.5 ± 9.5 yr). The differences between our results and Hue et al. [5] results may be attributed, firstly to the larger proportion of severely obese adults enrolled in the present study and, secondly, to the methodological differences regarding frequency of acquisition the data on the force platform (200 Hz) and confounders adjusted in the regression models.

As obtained in the present study, our bivariate and multivariate models shown that obesity presents just a few correlations with PB, and most of them became non-significant after adjustments (Table 2). Also, the fourth quartile of BMI, waist-to-hip ratio, waist-to-height ratio, and %FBM showed significant worse PB. We found that the great severity of obesity and high central obesity presented the worse PB (Figure 1 and Table 3). Despite the distinct interpretation, our results are in agreement from those obtained in the study of Singh et al. [7], which describes that the extremely obese presented poor balance when compared to non-obese. According to previous studies [32–34], the visceral obesity and android body fat distribution, as well as age-related sarcopenia in quadriceps muscle, are related to PB. Also, our findings were consistent with the previous literature, showing the influence of obesity on PB only in more severe obese subjects and in situations with greater instability (e.g., ST and eyes closed) [7, 12, 35–37]. This may be explained by the distribution of FBM [15–17, 32, 33, 38] and mechanical constraints due to severe obesity [8, 35, 39], but, most of all, we suggested that is related to decreased of muscular strength [34, 35] and possible related to fatigue [7], presence of comorbidities [18, 40–43] and poor physical fitness and PADL [17].

From an artificial increase in body weight [44], it has been observed that the weight increase had a negative effect on maintaining PB standing upright. However, the aforementioned results should be analyzed with caution, since must be considered the distribution of excess of weight [17] and postural changes resulting from this increase, as well as the physical fitness and PADL. Similarly, loss of body weight, in turn, improves postural stability by effects on the alignment of the whole body and ameliorate the capabilities of the postural control system. This beneficial effect of loss of body weight is tightly related to the magnitude of the weight loss and due to the reduced contact of the plantar area [45]. Moreover, the weight gain is gradual and often centered in abdominal region as well as observed in pregnancy for example. Although women had their weight in the anterior abdominal region increased during pregnancy, no significant differences have been found static PB when comparing early pregnancy, advanced pregnancy, and at 2 months and 6 months postpartum [46]. These results may be attributed to postural adaptive changes assumed by those women and also reported that the decreased static PB occurs under visual deprivation condition [46], which is consistent with our findings (e.g. worse PB with eyes closed) and may represent a plausible and possible reason for our main results.

Morbid obesity may lead to the deficit of PB and greater effect of the trunk in the ML displacement [8, 47]. After specific PB training and weight loss program, PB can be improved [45, 48]. It is imperative to assess individual differences in regional distribution of body fat [15–17], which may be subject to genetic factors, diet, and PADL [17]. The sedentary to active lifestyle transition may lead to positive adaptations and cardioprotection that can turn the body more capable of performing exercise [17], as well as to maintain PB. Also, strength, power and aerobic training can improve balance and functional performance [48, 49]. The maintenance of cardiorespiratory fitness through physical activity and non-smoking is equally important, which the opposite such as a restrictive pattern on spirometry is significantly associated with increased COP area [19].

We observed a significant correlation between lower limb isokinetic muscle function and AP and ML displacement of the COP, especially in more difficult tasks (e.g., the ST stance with eyes closed). These results have already been described previously [35]. These findings were meaningful when to consider aging since maximal concentric lower extremity strength is reduced, especially decreased of maximal strength of the quadriceps from the fifth decade and its correlates with significant reductions in activities of lower extremity muscles [48].

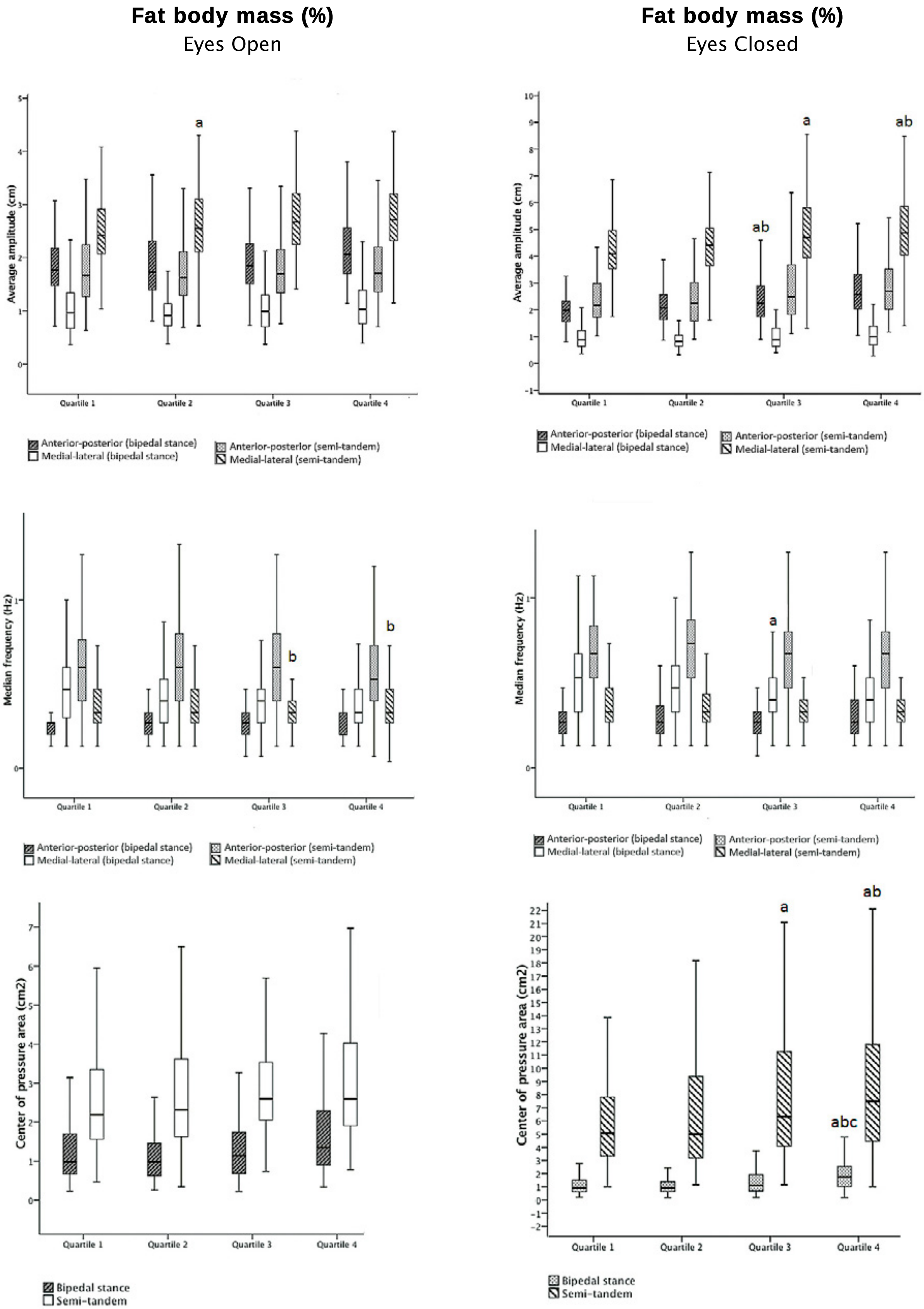

Figure 1 - Postural balance on the force platform in participants stratified according to the quartiles of the fat body mass (%).
Note: [ap] < 0.05 vs. quartile 1. [bp] < 0.05 vs. quartile 2. [cp] < 0.05 vs. quartile 3.

Accompanied by those changes, the decreased PADL can aggravate and even accelerate the loss of strength, becoming an important feature in the risk of falling and also generating fear of falling [50]. It is known that men who had recurrent falls presented lower PADL, lower amount of moderate-to-vigorous physical activity and more sedentary behavior when comparing with healthy men [50], which suggest lower exercise self-efficacy and more mobility difficulties.

Regarding the postural control system, the reduced plantar sensitivity alone could not incur significant PB disorders [51]. A study with individuals with type 2 diabetes reported that peripheral neuropathies had an independent influence on PB, both in eyes open and closed situations as well as on different surfaces [41]. This influence was greater with increasing BMI above 30 kg/m2 and in men. Additionally, the use of medication and presence of hypertension, diabetes, and dyslipidemia can also negatively influence balance by effects on the sensory and motor components of PB [18, 40]. Thus, our results reinforce the previous findings [41] regarding the independent associations of obesity with sex and cardiovascular risk factors and hence the occurrence of falls. Di Iorio et al. [52] found that the obesity was poorly associated with worse PB while the cumulative presence of cardiovascular risk factors lead to poor PB in elderly subjects.

Commonly used to diagnose obesity, the BMI cannot reflect important differences, when considering elderly or normal-weighted and physically active subjects [15–17, 53]. Our results demonstrate that, when establishing PB and body weight association, the most clinically relevant variable is the %FBM. Our results are in accordance with reported by Meng et al. [53]. A range of 2 to 3 times in visceral adiposity for each BMI classification may occur [17], which limits its applicability and justifies the results presented here. Thus, the use of body composition variables, measured by bioelectrical impedance, might be more suitable for identifying obesity-related PB changes (Figure 1).

Some limitations of the present study should be considered. The cross-sectional design of the study, absence of assessment of dynamic PB, and the greater number of female participants are the main limitations. However, the participants enrolled in EPIMOV Study present prevalence of comorbidity similar to describe for our population. Despite the discrepancies related to sex, our sample size was enough and the multivariate analyzes were carefully adjusted by sex as well as by the other main confounders. Thus, we are confident about the generalizability of the results presented here. On the other hand, our study has strengths. The most important were the adjustment for objective and precise measures of physical activity and fitness, such as PADL by a triaxial accelerometer, isokinetic muscle function and peak V'O2 in CPET.

We can conclude that obesity per se presents little influence on maintaining static PB. Additionally, the obesity seems not to determine the occurrence of falls among subjects over 40 years old.

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