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Balance and Mobility Relationships in Older Adults: a Representative Population-Based Cross-sectional Study in Madeira, Portugal

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Running head: Balance and Mobility in Older Adults

Highlights

- Balance and mobility were negatively associated with age and BMI;
- Men presented better balance and mobility performances than women;
- Balance and mobility were positively related to physical activity;
- Functional fitness explained the largest part of variance in balance and mobility;
- Aerobic endurance had the strongest contribution to explain balance and mobility.

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Abstract

Background: Balance and mobility impairments are important modifiable risk factors associated with falls in older people.

Purpose: To investigate how different functional fitness components relate to balance and mobility, after controlling for age, sex, body mass index (BMI), and different physical activity (PA) domains.

Methods: This representative cross-sectional study included 802 individuals, 401 males and 401 females (69.8±5.6 years) from Madeira, Portugal. The Fullerton Advance Balance (FAB) scale was used to assess balance. Mobility in terms of gait velocity, cadence, stride length, and gait stability ratio (GSR) were assessed using the 50-foot Walk test. PA was assessed through a face-to-face interview using the Baecke questionnaire, and functional fitness was assessed with Senior Fitness tests (strength, flexibility, and aerobic endurance).

Results: Balance and mobility were negatively associated with age and BMI, and positively related to PA and functional fitness. Moreover, male presented better performance in balance and mobility. Hierarchical multiple regression analyses showed that functional fitness explained the highest amount of variance in balance and all mobility parameters (over and above age, sex, BMI, and PA). Specifically, entering functional fitness components significantly increased explained variance in FAB (+ 19%), gait velocity (+ 25%), cadence (+ 15%), stride length (+ 9%), and GSR (+ 31%). In these models, aerobic endurance consistently had the strongest contribution.

Conclusion: Strength, flexibility, and especially aerobic endurance, over and above non-modifiable variables like age and sex, are related to better performances in balance and mobility and, thereby, possibly prevent falls in older people.

Key-words: balance; functional fitness; gait pattern; physical activity; falls' risk factors

1. Introduction

Balance impairments and mobility declines (e.g., gait speed decline, stride length decrease, and cadence decrease) are important modifiable risk factors associated with falls in older people (Rose, 2010). Falls, which are common in adults aged 65 years or older, are considered one of the leading causes of injury (Jin, 2018). Due to the increased risk of falling in old age for many reasons (e.g., weakness and frailty, balance problems, cognitive problems, vision problems, medication, acute illness, and other environmental hazards), designing specific fallprevention strategies based on modifiable predictors should be a priority at the communitydwelling setting (Jin, 2018; Pengpid & Peltzer, 2018).

Age-associated changes in gait pattern (Doyo, Kozakai, Kim, Ando, & Shimokata, 2011), body- posture stability (Gill et al., 2001), dynamic balance (Demura, Yamaji, & Kitabayashi, 2005), and static balance (Lohne-Seiler, Kolle, Anderssen, & Hansen, 2016), consistently favor the youngest older adults compared to oldest. On the other hand, sex-related differences in balance and mobility in community-living older adults have not been consistent (Lohne-Seiler et al., 2016; Demura et al., 2005; Doyo et al., 2011). Nevertheless, it remains unclear which factors may reverse, or at least slow down the rate of functional decline in multiple systems associated with balance and mobility (i.e., cardiovascular, pulmonary, musculoskeletal, nervous, sensory, and cognitive systems). Therefore, this study seeks to disentangle the contribution of lifestyles and functional fitness components in explaining variance in balance and mobility, after controlling for non-modifiable variables (i.e., age and sex) and other risk factors. For instance, among the variables that are considered common risk factors for balance and mobility impairments are low physical activity (PA) and obesity (Brown & Flood, 2013; WHO, 2015). There is evidence that regular PA in older adults is associated with improved static and dynamic daily motor tasks (Dawe et al., 2018; Pau, Leban, Collu, & Migliaccio, 2014), as well as reduced major physical disability (Pahor et al., 2014). However, it is still unclear whether PA prevents or delays mobility disability and the frequency, intensity, and type that is most effective. Difficulties related with different methods to assess PA, many and varied types of PA, and difficulties associated with tracking especially long-term adherence to unsupervised activity causes inconsistencies in the results reported. Regarding obesity, there is an expected linear relationship between excessive body fat and an increased risk of impaired physical functioning (Rikli & Jones, 2013). Nevertheless, there is some evidence on the relationships between adiposity and decline in mobility (Benavent-Caballer et al., 2016).

Preserving functional mobility and independent lifestyle in later years depends to a large degree on how well older adults maintain functional fitness capacities such as muscular strength, aerobic endurance, flexibility, agility, and dynamic balance (Rikli & Jones, 2013; WHO, 2015).

Despite the fact that there is a strong scientific evidence that maintaining functional fitness capacity seems fundamental to keep balance and mobility in old age, there is only little evidence regarding the particular fitness level needed for maintaining physical independence, as well as, regarding the individual contribution of different functional fitness components to explain interindividual differences in balance mobility. Although prior studies have addressed possible risk factors for balance and mobility impairments, a more detailed understanding of the individual contribution of different functional fitness components, after controlling for related nonmodifiable and modifiable factors in representative samples, is still needed. This knowledge will be important to design interventions tailored to prevent or even reverse balance and mobility problems.

The present study investigated how different functional fitness components (i.e., lower body strength, lower body flexibility, and aerobic walking endurance) relate to balance and mobility, over and above age, sex, body mass index (BMI), and different PA domains.

2. Methods

2.1 Study design and participants

This cross-sectional study included 802 individuals, 401 males and 401 females (69.8±5.6 years). In total, the sample comprised 2.1% of the older adults from the Autonomous Region of Madeira (ARM), Portugal, a representative sample. Participants were sufficiently mobile and independent to visit the laboratory at the University of Madeira (UMa) on their own. Proportional regional (geographic) representation was determined by stratified sampling based on Census 2001 data from the Statistics Portugal, the Portuguese National Institute of Statistics (Statistics Portugal, 2002) with the number of subjects per age cohort and sex serving as stratification criteria.

The study was approved by the UMa, the Regional Secretary of Education and Culture, and the Regional Secretary of Social Affairs Committees. All participants were informed about the nature and purposes of the study and written informed consent was obtained from each subject. All assessments were conducted in the Human Physical Growth and Motor Development Laboratory at the UMa by trained research personnel in 2009.

2.2 Instruments

The Fullerton Advance Balance (FAB) scale is a performance-based measure that comprehensively addresses the multiple dimensions of balance, through static and dynamic balance activities performed in different sensory environments (Rose, Lucchese, & Wiersma, 2006). The application of the FAB scale requires that the participant performed static and dynamic balance activities. The FAB scale includes the following 10-tasks: (1) standing with feet together and eyes closed, (2) reaching forward to retrieve an object (pencil) held at shoulder height with outstretched arm, (3) turning 360 degrees in a right and left direction, (4) stepping up and over a 15 cm bench, (5) tandem walking, (6) standing on one leg, (7) standing on foam with eyes closed, (8) jumping for distance, (9) walking with head turns, (10) and recovering from an unexpected loss of balance. Each test item is scored using a 4-point ordinal scale (0–4), with a maximum score of 40 possible points. The Fab scale has been translated to Portuguese (Baptista and Sardinha, 2005) and it is largely used in clinical contexts for screening and identifying changes in balance abilities of independent older adults, as an alternative to the Berg scale, which shows ceiling effects, especially in this population. The Portuguese version of the FAB scale has previously been shown to be a valid and reliable measure of balance (Gouveia et al., 2016). The predictive validity of the FAB scale relative to fall risk has also been demonstrated (Hernandez & Rose 2008). A detailed description of the test administration protocol, equipment needed, and instructional video is provided elsewhere Rose (2010). For this study, an extensive preparation of the field team and a detailed pilot study were conducted before the assessments. First, a theoretical explanation of the protocols and tests to be performed was provided to all field team members. Second, the physical assessments were self-administered among team members during preliminary training (5 days, 2 training sessions per day, with a duration of 2 hours). Third, two training sessions were conducted with a group of older adults (6 men and 14 women) belonging to a regular PA program. The final preparation of the field team was completed with a pilot study that included a sample of 8 men and 23 women with a mean age of (67.0±6.6 years). Test-retest reliability was established based on two testing sessions conducted one week apart. The results from both tests were pooled and the intra-class correlation (R) coefficients and their confidence intervals determined. The correlations for the total FAB scale score was 0.96 (95% CI: 0.92; 0.98).

Limitations in functional mobility were measured using the 50-foot Walk Test (Rose, 2003). Participants were required to walk a distance of 50 feet at preferred speed, with the purpose of calculating gait parameters. The number of steps taken over the 50-foot distance was counted by visual observation in order to calculate cadence (steps per second) and stride length (feet) (Rose, 2003). The gait stability ratio (GSR) was calculated from cadence (steps/sec) and velocity (ft/sec) was expressed in units of steps per foot. A full description of the test administration instructions for the 50-foot walk test is reported in Rose (2003).

PA was assessed trough a face-to-face interview using the Baecke questionnaire (Baecke, Burema, & Frijters, 1982). This questionnaire includes a total of 16 questions grouped into three specific domains: PA at work/household, sport, and leisure time besides sports. For the current study, the questionnaire also provides a measure of total PA that is the sum of these three specific domains (for validations see e.g. Gouveia et al., 2014).

Functional fitness was assessed with the Senior Fitness Tests (SFT; Rikli & Jones, 2013). The test battery comprises different components including lower body strength (chair stand test), lower body flexibility (chair sit-and-reach test), and aerobic walking endurance (6-min walk test). A detailed description of the evaluation procedures, namely, equipment, procedures, scoring, and safety precautions, can be found in the SFT manual (Rikli & Jones, 2013).

Body mass (kg) was measured with a balance scale accurate to 0.1 kg (Seca alpha digital scales model 770, Germany) and standing height (cm) with a Holtain stadiometer (Holtain Ltd., Crymych, United Kingdom) accurate to 0.1 cm. Subjects wore light, indoor clothing without shoes during the measurements. Body mass index (BMI) was determined by dividing with in kilograms by height in meters squared ($BMI = Kg \cdot m^2$).

2.3 Statistical Analyses

First, we inspected bivariate correlations of FAB, gait velocity, cadence, stride length, and GSR with age, sex, BMI, PA, lower body strength, lower body flexibility, and aerobic walking endurance. Second, hierarchical multiple regression analyses were conducted to investigate the individual amount of variance in FAB score, gait velocity, cadence, stride length, and GSR that were explained by non-modifiable variables (age and sex, both entered in step 1), BMI and PA (both entered in step 2), and the functional fitness components (lower body strength, lower body flexibility, and aerobic walking endurance, entered in step 3). The level of confidence was set at 95%. Data analysis was performed using IBM SPSS Statistics version 24 (SPSS Inc., an IBM Company, Chicago, Illinois, U.S.A.).

3. Results

Table 1 Bivariate *correlations of balance and mobility age, sex, BMI, physical activity and functional fitness*

	Balance	Mobility			
	FAB	Gait Velocity	Cadence	Stride Length	GSR
Age (years)	-.37***	-.34***	-.28***	-.27***	.28***
Sex (1/2)	-.19***	-.13***	.12***	-.28***	.26***
BMI (kg/m2)	-.13***	-.10**	-.02	-.12***	.12***
PA (n)	.34***	.38***	.31***	.32***	-.35***
LB-Strength (n)	.53***	.49***	.40***	.39***	-.43***
LB-Flexib. (cm)	.30***	.25***	.23***	.19***	-.22***
Aerobic End. (m)	.61***	.68***	.46***	.64***	-.67***

$^{*}p$ <.05; ** p < .01; *** p <.001.

FAB – Fullerton Advance balance Scale; GSR – Gait Stability Ratio; Sex - 2= female, 1= male; LB – lower body; BMI - body mass index; PA – Physical Activity; LB-Flexib. – lower body flexibility; Aerobic End. – Aerobic walking Endurance

An inspection of bivariate correlations showed that balance (FAB) was negatively associated to age, sex, and BMI, and positively related to PA and all three functional fitness components, i.e., body strength, flexibility, and aerobic walking endurance. Similar results were seen for gait velocity and stride length, as well as for GSR (taking in consideration that, increased GSR indicates that older adults take more steps per unit of distance in order to maintain balance). For cadence, the correlations were negatively related to age and were non-significant for BMI, and positively related to all other variables (Table 1).

Table 2 shows the results of hierarchical multiple regression analyses. In step 1, age and sex explained 17%, 14%, 9%, 15%, and 15% of variance in FAB, gait velocity, cadence, stride length, and GSR, respectively. In step 2, BMI and PA were entered as additional predictors and increased explained variance in FAB score (+ 10%), gait velocity (+ 11%), cadence (+ 7%), stride length (+ 9%), and GSR (+ 9%). Entering the functional fitness components as additional predictors in step 3 significantly increased explained variance in FAB score (+ 19%), gait velocity (+ 25%), cadence (+ 15%), stride length (+ 9%), and GSR (+ 31%), with total variance being explained by the model as a whole of 46% in FAB score, 50% in gait velocity, 31% in cadence, 52% in stride length, and 55% in GSR.

Table 2 *Summary of hierarchical regression analyses with age, sex, BMI, physical activity and functional fitness predicting balance and mobility*

	Balance			Mobility											
	FAB			Gait velocity			Cadence			Stride Length			GSR		
	I	II	III	I	II	III	I	II	III	I	II	III	I	II	III
	β	β	β	β	β	β	β	β	β	β	β	β	β	β	β
Age (years)	-.37***	-.33***	-.17***	-.34***	-.29***	-.11***	-.28***	-.24***	-.10*	-.27***	-.23***	-.07*	.28***	.24***	.07*
Sex (1/2)	-.19***	-.18***	-.08*	-.14***	-.13***	.02	.12**	.12***	.24***	-.29**	-.28***	-.15***	.26**	.26***	.12***
BMI (kg/m2)	-	-.09*	-.04	-	-.06	.01	-	-.03	.02	-	-.05	.01	-	.06	.00
PA (n)	-	.29***	.09*	-	.34***	.13***	-	.27***	.10*	-	.28***	.11***	-	-.31***	-.11***
LB-Strength (n)	-	-	.20***	-	-	.10**	-	-	.16**	-	-	.01	-	-	-.03
LB-Flexib. (cm)	-	-	.10**	-	-	.02	-	-	-.01	-	-	-.03	-	-	-.04
Aerobic End. (m)	-	-	.35***	-	-	.54***	-	-	.38***	-	-	.52**	-	-	-.55***
R^2	.17	.27	.46	.14	.25	.50	.09	.16	.31	.15	.23	.43	.15	.24	.47
F for change in R^2	83.9***	50.0***	97.2***	61.9***	62.6***	132.6***	41.3***	33.7***	59.2***	71.4***	42.9***	91.2***	68.7***	52.2***	115.5***

* p <.05; ** p <.01; *** p <.001. Model I – Age, and Sex; Model II - Age, Sex, BMI and Physical Activity; Model III - Age, Sex, BMI, Physical Activity, Lower Body Strength; Lower Body Flexibility and Aerobic Walking endurance.

FAB – Fullerton Advance balance Scale; GSR – Gait Stability Ratio; Sex - 2= female, 1= male; LB – lower body; BMI - body mass index; PA – Physical Activity; LB-Flexib. – lower body flexibility; Aerobic End. – Aerobic walking Endurance.

4. Discussion

In the present study, we found that balance and mobility were negatively associated to age, and BMI and positively related to PA and functional fitness components (lower body strength, lower body flexibility, and aerobic walking endurance). Moreover, male presented better balance and mobility parameters. In addition, the three studied functional fitness componentes, together, explained the largest part of variance in balance and all mobility parameters, over and above the contributions of age, sex, BMI, and PA.

These findings are in line with other studies in older adults suggesting a negative relationship between balance and mobility parameters with age, after controlling for modifiable and nonmodifiable factors such as sex, chronic diseases, anthropometric variables, socioeconomic status, functional fitness and PA (Demura et al., 2005; Doyo et al., 2011; Lohne-Seiler et al., 2016). This negative relationship is likely due to the age-related functional decline (i.e., changes in structure, capacity, and endurance) in cardiovascular, pulmonary, musculoskeletal, nervous, sensory, and cognitive systems.

While several studies have investigated sex-related differences in balance and mobility in community-living older adults (Demura et al. 2005; Doyo et al. 2011; Lohne-Seiler et al., 2016), findings regarding the nature of these sex differences have not been consistent. In our study, being female was negatively related with balance, gait velocity, stride length, and with a worse score in GSR. These results are in line with evidence on better performance in men in comparison to women in balance (Bryant, Trew, Bruce, Kuisma, & Smith, 2005) mobility parameters (Doyo et al., 2011), and general functional fitness components (Gouveia et al., 2013). However, some studies have reported better postural stability (Puszczalowska-Lizis, Bujas, Jandzis, Omorczyk, & Zak, 2018), one leg standing (Lohne-Seiler et al., 2016), and dynamic balance (Demura et al., 2005) in women in comparison to men. This lack of consistency described in the literature could be related to sex differences in the strategies to keep balance and mobility (Rose, 2010) or differences related to functional fitness components (Gouveia et al., 2013; Lohne-Seiler et al., 2016).

The level of daily PA has been identified as an important factor for the onset of disability and fall risk (Dondzila, Perry, & Bornstein, 2018; WHO, 2015). The association between balance, mobility and PA observed in our study is consistent with the findings of other studies (Dawe et al., 2018; Mertz, Lee, Sui, Powell, & Blair, 2010; Michael et al. 2009, Pau et al., 2014). Our study supports the growing evidence that adequate levels of PA (at household, sports, and leisure time domains) may be an important contributor for maintaining balance and mobility assessed in a multiple dimension perspective (e.g., sensory, motor, musculoskeletal, cognitive).

In our study we evaluated the role of different functional fitness components to predict FAB score and gait velocity, cadence, stride length, and GSR, over and above non-modifiable variables (age and sex) as well as BMI and PA. Hierarchical multiple regression analyses showed that the three functional fitness parameters explained the greatest variance in FAB score, gait velocity, cadence, stride length, and GSR. Therefore, these results suggest that maintaining or improving functional fitness components may be of highest importance to maintain balance and mobility and, consequently, prevent falls in older people. This also suggests that age should not be a barrier to PA promotion due to the fact that positive improvements are attainable at any age (Gouveia et al., 2016; Cadore, Rodríguez-Mañas, Sinclair, & Izquierdo, 2013).

Notably extending the literature, disentangling the investigated functional fitness components in more detail regarding their specific contribution, aerobic walking endurance was the strongest predictor for FAB, gait velocity, cadence, stride length, and

GSR. Compared to that, lower body strength and lower body flexibility made only a minor contribution. These results underline the importance of aerobic walking endurance given on frequency, intensity, and type recommendations for older adults by many organizations, such as American College of Sport Medicine (ACSM, 2017). Following this recommendation, apart from muscle strengthening/endurance exercise (≥ 2 d · wk^{-1}), flexibility (≥ 2 d · wk^{-1}), and neuromotor exercise (2 – 3 d · wk^{-1}), to promote and maintain health, older adults should perform moderate intensity aerobic exercise (≥ 5 d · wk^{-1}), or vigorous intensity aerobic exercise (≥ 3 d · wk^{-1}), or some combination of moderate and vigorous aerobic exercise (3 – 5 d · wk^{-1}, ACSM, 2017). Our results dovetail with these recommendations taking in consideration the strongest contribution by aerobic walking endurance in explaining interindividual differences in balance and mobility parameters, when strength and flexibility were controlled for.

We acknowledge that the cross-sectional design of the present study limits conclusions regarding the direction of the relationships between the identified predictor variables and balance and mobility parameters. Although the Baecke questionnaire used on this study to assess PA has been shown to have acceptable reproducibility (Gouveia et al., 2014), potential difficulties to accurately recall past sport and leisure activities could introduce bias and lead to misclassification. On the other hand, this study is unique in some aspects. First, the data were obtained from a representative sample of community-dwelling older adult men and women from Madeira, Portugal, characterized by a very unique older adult population as witnessed by their lower rates of retirement, high prevalence of gainful employment in farming, and reduced dependency on social assistance. Second, balance was assessed using the FAB scale, a performance-based measure that is feasible in clinical practice and that comprehensively addresses the multiple dimensions of balance through static and dynamic balance activities

(Hernandez & Rose, 2008). Lastly, high relevance was given to potentially modifiable factors of balance and mobility so that the present findings may be considered in the design of future research specially focused on community-based interventions to enhance older adults' balance and mobility.

In conclusion, the present study supports the idea that better performances in lower body strength, lower body flexibility, and especially aerobic walking endurance, over and above non-modifiable variables (i.e., age and sex), PA, and BMI, are related to better performances in balance and mobility and, thereby, possibly prevent falls in older people.

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