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Article

Comparison of Physical Performance and Muscle Thickness between Older Women with High and Low Fall Risk: A Bayesian Approach

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Abstract

Objective: The present study aimed to compare performance in different functional tests predicting falls between older adults with low and high fall risk. **Methods:** Seventy-one community-dwelling older women volunteered for this study. Berg Balance Scale (BBS) was used to stratify the sample as: low and high risk for fall (BBS cutoff = ≥ 50 points). The performance in Time Up and Go Test (TUGT), 5-repetition sit-to-stand test (5xSST), 3-meter walk test (3mWT), 3-meter backward walk test (3mBWT). The elbow flexor and knee extensor muscle thickness was obtained by ultrasound (USD). A linear mixed model analysis was used to determine between-group differences in functional mobility and muscle thickness, and Bayesian analysis was applied to check the probability to replicate the same results (i.e., the magnitude of the evidence). **Results:** The low fall risk group exhibited significantly better performance only in 3mWT (mean difference = 0.84 s [95% CI: 0.40 to 1.29 seconds]; $p = 0.001$) and 3mBWT (mean difference = 1.54 seconds [95% CI: 0.21 to 2.85 seconds]; $p = 0.024$). The Bayes Factor (BF) for performance on the 3mWT and 3mBWT shows that the low fall risk group has a probability of 98.7% ($BF_{10} = 77.3$) and 99.7% ($BF_{10} = 368$), respectively, to perform better than the high fall risk group. **Conclusion:** Based on inferential and Bayesian analysis, the performance in 3mWT and 3mBWT was classified as very strong to excellent instruments, respectively, to differentiate older women with high fall risk.

Keywords: aging; bayesian analysis; body composition; functional mobility

Introduction

Aging is associated with changes in body composition, such as progressive loss of lean mass and muscle strength, which influences anthropometric and functional parameters in older adults, being risk factors associated with increased falls (Scott et al. 2017). Approximately 1 in 3 older adults fall each year, representing a common clinical problem in the elderly population, more prevalent in females, likely due to greater physical frailty, lower lean mass, and muscle strength (Fonad et al., 2015; Moraes et al., 2017).

Fall events in older adults result from postural instability, with balance impairment recognized as its main predictor (Scott et al., 2007). In this sense, susceptibility to falls is associated with decline in functional performance, reduced effectiveness of postural responses, reduced sensory acuity, musculoskeletal and neuromuscular impairment, deconditioning associated with inactivity, as well as psychological and environmental factors (Figueiredo & Santos, 2017), which has been evaluated through measures of muscle strength and mass, autonomy and mobility/functionality, and instruments that assess fall risk. Thus, early identification of older women at higher risk of falls is an effective strategy to prevent possible negative outcomes, such as morbidity, mortality, and hospitalization due to falls (Hopewell et al., 2018; James et al., 2020).

Various instruments are used to assess fall risk, but the Berg Balance Scale (BBS) stands out as a qualitative measure consisting of functional clinical tests used to evaluate balance in older adults during daily activities (Berg, 1989; Miyamoto et al., 2004). The BBS is distinguished by its psychometric properties of reliability and validity, being considered the gold standard test for assessing fall risk, proving even more effective in predicting future falls than in confirming fall history in older adults (Alghwiri & Whitney, 2012; Lin et al., 2004; Muir et al., 2008; Steffen et al., 2002).

Clinical tests developed to assess functional capacity are used to evaluate different dimensions of balance in older adults, to assist in clinical decisions regarding balance deficit and development of fall prevention strategies. Studies evaluating factors associated with higher fall risk, as well as the relationship and complementarity of instruments that assess this risk, are increasingly necessary to help select ideal methods for fall risk assessment, which can be a determining factor for screening and early intervention in older adults with high fall risk (Soares et al., 2014). Performance in functional tests such as Time Up and Go Test (TUG), Five Times Sit-to-Stand Test (LS5), 6-meter Walk Test (6mWT) are widely reported in literature as factors associated with higher fall risk in older adults. The 3-meter Backward Walk Test (3mBWT) is a recent proposal that also aims to assess fall risk in older adults. Initial results regarding association with falls in older women are promising, but studies comparing it with other fall predictors are still scarce.

Falls in older adults are a public health concern, and healthcare professionals' ability to detect future falls through simple screening instruments is a fundamental element in their prevention and reduction of risk factors, especially in individuals classified as high fall risk. Thus, this study aimed to compare performance in different functional tests predicting falls between older adults with low and high fall risk.

Materials and Methods

Sample

Seventy-one community-dwelling older women (74.5±8.5 years) volunteered for this study. They were aged 60 years or older and without acute diseases or cognitive impairment (Almeida, 1998; Bertolucci et al., 1994). All participants demonstrated independent ambulation and were free from limb amputations or skin lesions that affected their gait pattern.

The study was conducted in accordance with the Declaration of Helsinki, and the protocol was approved by the Ethics Committee of Universidade Estadual do Sudoeste da Bahia (protocol n. 2.783.516) on July 24, 2018. All volunteers signed the Informed Consent Form.

Physical Performance Measures

For functional balance assessment, the Berg Balance Scale (BBS) was used to evaluate balance based on 14 functional daily living activities. These activities involve static and dynamic balance control tasks, which include sitting, standing, leaning, among others, and indicate the subject's balance when performing motor activities with an overall score ranging from 0 (severely impaired balance) to 56 (best test performance/excellent balance) points maximum (Berg, 1989; Miyamoto et al., 2004).

A meta-analysis conducted by Lusardi et al. (2017) identified a cut-off point of 50 points on the BBS to predict future fall risk; therefore, this was adopted in this study as the cut-off point for stratification of older women with high (≥ 50 points) or low (< 50 points) fall risk.

Functional mobility assessment was performed using the Time Up and Go Test (TUGT), which is a sensitive and specific measure to identify older adults at risk of falling and is widely used to assess functional mobility in this population (Podsiadlo & Richardson, 1991). The lower limb strength was assessed using the "5-repetition sit-to-stand test" (5xSST) as used by (Pinheiro et al., 2016). The 3-meter walk test (3mWT) (Guralnik et al., 1995) and the 3-meter backward walk test (3mBWT) (Winter et al., 1989) were used to assess gait performance.

Muscle Thickness Measurements

Transverse ultrasound images were obtained from right Brachial (Br), Biceps Brachial (BB), Vastus Lateralis (VL), and Rectus Femoris (RF) muscles using a B-mode 2-dimensional ultrasound (USD) imaging device (Figlabs[®] FP 102), as described in Matos De Araujo et al. (2023). A linear array transducer (Figlabs[®], L471, sampling frequency of 7.0 MHz) was used, and a single trained and qualified evaluator performed all USD measurements, which were obtained with volunteers remaining upright, with their upper limbs relaxed and with palms facing forward, and the transducer was positioned perpendicularly to muscular tissue and underlying bone as described by Takai et al. (2014).

The elbow flexor muscle thickness was recorded at 60% of the distance between the lateral epicondyle and the acromial process, as proposed by Abe et al. (1994). During the image recording, the pressure was kept to a minimum to avoid excess compression and distortion, and a generous amount of contact water-soluble gel was applied (Bemben, 2002).

Subcutaneous adipose tissue at the tissue-muscle and muscle-bone interfaces were identified in the USD image and used to determine the muscle limits, guiding the muscle thickness measurements for each of the elbow flexors (EF) and knee extensors (KE) muscle groups (Matos De Araujo et al., 2023).

Statistical Analysis

A linear mixed model analysis was used to determine between-group differences in functional mobility and muscle thickness, taking groups as a fixed factor and age as a random factor. Normality of the data was not checked since the linear mixed model analysis used is reportedly robust in addressing Type 1 error rates when analyzing non-normal data (Arnau et al., 2012). The critical alpha was set at 0.05, and all procedures were carried out in SPSS (SPSS Inc., Chicago, IL).

Results are presented as mean \pm SD, mean difference between groups, and 95% confidence interval (95% CI). The mean differences and their 95% CI were reported and interpreted as a measure of effect size, as this approach allows identifying the direction and magnitude of the effect, justifying its use as an adequate measure of effect size (Herbert et al., 2011). To check the probability to replicate the same results (ie, the magnitude of the evidence), we applied the Bayes Factor (BF) hypothesis testing analyses (Dos Santos et al., 2021; Gönen et al., 2005; Peixoto et al., 2021). Individual comparisons were based on the default t-test with a Cauchy (0, $r = 1/\sqrt{2}$) prior. The outcomes were classified as anecdotal (BF10=1-3), moderate (3-10), strong (10-30), very strong (30-100), and extreme (>100) favoring the alternative hypothesis; or anecdotal (BF10=1-0.33), moderate (0.33-0.1), strong (0.1-0.03), very strong (0.03-0.01), and extreme (<0.01) favoring the null hypothesis (Lee and Wagenmakers' classification) (Jeffreys, 1998; Quintana & Williams, 2018). To calculate the probability of finding the same results again, we divided the actual BF10 value by BF10+1. We made all BF analyses using jamovi (The jamovi project, 2020).

Results

The mean age of the studied older adults was 74.5 ± 8.5 years old. When stratified according to fall risk, the high fall risk group was significantly older than the low fall risk group (low fall risk group = 70.8 ± 6.2 years old; high fall risk group = 79.7 ± 8.6 years old; $p < 0.05$). Weight (low fall risk group = 66.9 ± 9.4 Kg; high fall risk group = 63.1 ± 8.6 Kg; $p > 0.05$), height (low fall risk group = 152.9 ± 6.5 cm; high fall risk group = 151.8 ± 6.1 cm; $p > 0.05$), and body mass index (low fall risk group = 28.7 ± 4.1 cm; high fall risk group = 27.3 ± 4.8 cm; $p > 0.05$) were not significantly different between high and low risk groups. Table 1 presents data from chronic diseases, such as diabetes and osteoarthritis, the history of falls in the last 12 months, and the usage of psychotropic medications from the studied older women according to the fall risk.

Table 1. Sample characteristics. data are reported as absolute and relative frequencies [n (%)].

Variable		Low risk (n = 42)	High risk (n=29)	P value
Diabetes	No	33 (78.6)	24 (82.8)	0.663
	Yes	9 (21.4)	5 (17.2)	
Osteoarthritis	No	33 (78.6)	21 (72.4)	0.550
	Yes	9 (21.4)	8 (27.6)	
Fall in the Last 12 Months	No	31 (75.6)	18 (60.0)	0.160
	Yes	10 (24.4)	12 (40.0)	
Psychotropic Medications	No	41 (97.6)	25 (86.2)	0.151
	Yes	1 (2.4)	4 (13.8)	

Only the performance in the walking tests (i.e., forward and backward) demonstrated a significant between-group difference ($p < 0.05$). The low fall risk group exhibited significantly better performance (3mWT: mean difference = 0.84 seconds [95% CI: 0.40 to 1.29 seconds]; $p = 0.001$ / 3mBWT: mean difference = 1.54 seconds [95% CI: 0.21 to 2.85 seconds]; $p = 0.024$). The Bayes Factor analyses for performance on the 3mWT and 3mBWT show that the low fall risk group has a probability of 98.7% ($BF_{10} = 77.3$) and 99.7% ($BF_{10} = 368$), respectively, to perform better than the high fall risk group. The performance in the TUGT exhibited a moderate [85.7% ($BF_{10} = 6.00$)] probability of being better in the low fall risk group, while the elbow flexor muscle thickness exhibited an anecdotal [56.9% ($BF_{10} = 1.32$)] probability of being greater in the low fall risk group. In contrast to other variables, the 5xSST and knee extensor muscle thickness exhibited a posterior probability of 30.7% ($BF_{10} = 0.444$) and 47.9% ($BF_{10} = 0.921$) between groups, respectively, classified as anecdotal favoring the null hypothesis. The results from inferential and Bayesian statistics are presented in Table 2.

Table 2. Inferential and Bayesian analysis for the comparison of studied variables between community-dwelling senior women stratified according to the Berg Scale Score (cut off ≥ 50 points).

Variable	Low risk (n = 42)	High risk (n=29)	Mean difference (95% CI)	P value	BF _{10, U}	Probability %
TUGT (s)	8.98 (1.94)	10.63 (3.02)	0.53 (-0.71 to 1.77)	0.398	6.00 ^M	85.7

	12.21	13.18	0.78			
5xSST (s)				0.389	0.444 ^a	30.7
	(3.00)	(3.93)	(-1.05 to 2.60)			
	3.34	4.19	0.84			
3mWT (s)				0.001	77.3 ^v	98.7
	(0.66)	(1.19)	(0.40 to 1.29)			
	5.16	7.96	1.54			
3mBWT (s)				0.024*	368 ^E	99.7
	(1.46)	(3.70)	(0.21 to 2.85)			
	2.64	2.40	-0.13			
EF_MT (cm)				0.323	1.32 ^A	56.9
	(0.43)	(0.47)	(-0.41 to 0.14)			
	3.45	3.16	-0.10			
KE_MT (cm)				0.576	0.921 ^a	47.9
	(0.66)	(0.54)	(-0.47 to 0.26)			

Letters indicate the outcome classified as: A= anecdotal; M = moderate; V = very strong; E = extreme favoring the alternative hypothesis; a = anecdotal favoring the null hypothesis. EF_MT = elbow flexor muscle thickness; KE_MT = arm flexor muscle thickness. (*) Significantly different ($p < 0.05$).

Discussion

This study aimed to compare performance in different functional tests predicting falls between older women with low and high fall risk. After age-adjusted comparison, we found that the performance in 3mWT and 3mBWT were statistically better in the low fall risk group. Bayesian analysis indicated very strong (98.7%) extreme probability (99.7%) of between-group difference, for 3mWT and 3mBWT, respectively, indicating that they are excellent parameters to differentiate older women with low and high fall risk.

Walking performance is recognized as a relevant parameter to measure functionality in a wide variety of populations, being attested as a “vital sign” (Middleton et al., 2015). Indeed, the act of walking depends on a set of factors, such as strength, postural balance, spatial orientation, proprioception, and ability to make constant and rapid adjustments to position changes, among others, which makes the measures of gait performance an excellent instrument to discriminate people with low and high fall risk, especially older adults, since aging is associated with a natural decline of all factors that influence gait performance.

Indeed, walking without adequate visual feedback, as in backward walking, makes it difficult to plan foot support position, generating slower movement to maintain safety, which will tend to be even slower in older adults who tend to exhibit sensorimotor impairment (Moraes & Castro, 2001). In this context, walking backward may be a particularly important factor as a fall predictor in individuals with any condition that prevents this task (McVey et al., 2013), especially because few daily situations require the execution of this type of locomotion that primarily depends on good sensorimotor integration.

Based on the premise that the older adults present sensorimotor decline, impacting the ability to integrate sensory information and generate adequate motor responses, applying motor challenges, like walking backward, may highlight differences in motor competence between older adults less

and more prone to falls, which perhaps cannot be detected with more conventional tests. Our results corroborate this premise, since in the present study, volunteers presented good motor capacity (mean BBS score = 49.5 points (median = 51 points) and tests widely reported as excellent fall predictors in older adults, such as TUGT, 5xSST, showed no difference between the studied groups. Additionally, muscle mass also does not seem to be a determinant of low and high fall risk conditions in older women with the characteristics of our study sample.

Our results corroborate with Fritz et al. (2013), indicating that backward gait performance seems to be the best predictor of fall risk in older adults. However, in that study, the sample exhibited a mean age 10 years higher than in our study sample. Additionally, the authors stratified the older adults according to fall history, while in our study, we decided to stratify according to a recognized cut-off point in BBS. This option is based on the fact that BBS demonstrates good ability to predict future falls, especially when considering high cut-off points (> 45 points) (Lima et al., 2018; Scott et al., 2007).

This recognized property of BBS in predicting future falls, without necessarily being associated with fall history, may justify the absence of association between a low BBS score (cut-off at 50 points) and fall history, observed in our study ($p = 0.160$). The fact that we adopted a higher cut-off point, following the findings from Lusardi et al. (2017), may have influenced this result.

In summary, our results support the hypothesis that gait performance, forward, but especially backward, may be more sensitive in identifying age-related factors, such as mobility and balance, being a promising clinical tool to assess fall risk in older women (Fritz et al., 2013; Laufer, 2005).

It is worth emphasizing some methodological aspects and possible limitations of this study. Regarding the limitations, the cross-sectional design does not permit any conclusions to be drawn about individual changes in the studied variables over time. Additionally, the sample was limited to older women, predominantly those with good functional mobility, as indicated by a mean score of 49.5 on the BBS (median = 51 points). However, these two issues could point to a relevant aspect of this study, since women are more prone to falls, and among subjects with higher functional mobility, as studied herein, it will be harder to stratify older adults according to the propensity to fall.

Conclusion

The results of this study verified that gait performance, walking forward (3mWT), but especially backward (3mBWT), has great potential to differentiate older women more prone to falls. Additionally, based on Bayesian analysis, the performance in 3mWT and 3mBWT was classified as very strong to excellent instruments, respectively, to differentiate older women with high fall risk, and TUGT, despite the absence of statistical difference in inferential statistics, also showed potential for this purpose, but with a moderate probability to differentiate. The good functional mobility of the studied sample could have conditioned these results, highlighting the need to implement motor challenges, such as walking backward, to stratify active older women with low and high fall risk.

Authors' Contribution: MSC and MHF contributed equally to the conceptualization, supervision, data analysis, and writing of the manuscript. CMA, RP, and JFSS contributed equally to the conceptualization, data analysis, and writing of the manuscript. All authors contributed to data collection, data interpretation and writing of the manuscript. All authors approved the final version of the manuscript.

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