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Agreement and predictive power of six fall risk assessment methods in community-dwelling older adults

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ABSTRACT

A large number of fall risk assessment methods are available with a variety of performances for screening the risk of falling in older adults, but their agreement for assessing the risk of falling remains unknown. This observational prospective cohort study describes the agreement and predictive power of methods to classify the risk of falling in older adults using prospective data and published cut-off values. Fifty-two participants aged 74 years (interquartile range 69–80) were assessed using the Berg Balance Scale, polypharmacy, Falls Risk Assessment Score, Fall Risk Assessment Tool, Fall Efficiency Scale, and Posturography. Nine participants (17 %) reported at least one fall after six months. Cochran's test showed different proportions of participants classified as at high risk of falling among all methods ($Q = 69.560$, $p < 0.001$). A slightly better-then-chance agreement was estimated between all FRA methods (Light's $\kappa = 0.074$, 95%CI [0.021; 0.142]). We found both global and pairwise agreement levels that question the agreement among fall risk assessment methods for screening community-dwelling older adults.

1. Introduction

Falls are a major burden for the population, ranking both as the leading unintentional injury and the 26th level of all-age disability-adjusted life-years globally (Kassebaum et al., 2016). Among the adults aged > 65 years, approximately 1 in 3 people fall every year and half of them fall more than once (Moylan & Binder, 2007). The high prevalence of falls poses high costs to the health system due to the need for medical and hospital care for fall-related injuries (Santos et al., 2015). Risk factors for falls are multiple and related, and the likelihood of a fall increases with the increasing number of risk factors (Deandrea et al., 2010; Yamashita, Noe, & Bailer, 2012). Intrinsic risk factors comprise age-related changes in all components of the sensory, cognitive, and neuromuscular systems related to the control of postural stability, as well as diseases affecting any of these systems, functional and cognitive deficits, and the use of psychoactive drugs. Extrinsic risk factors include the environment or activities that can disturb the postural stability (Deandrea et al., 2010; Yamashita et al., 2012). Because both the risk of falling and the rate of falls can be reduced using management programs or exercises following the application of multifactorial screening tools (Hill & Schwarz, 2004; Sherrington et al., 2017; Tricco et al., 2017), primary-to-secondary prevention actions are preferred to reduce the burden of falls in the older population (Mancini & Horak, 2009; National Institute of Health & Care Excellence, 2013).

Fall risk assessment (FRA) methods are an effective, systematic approach aiming at reducing the falls incidence and related morbidity (Chang et al., 2004; National Institute of Health & Care Excellence, 2013; Tricco et al., 2017). A considerable number of methods is available, most of them have cutoff values for stratification of risk of falling (Ghahramani, Naghdy, Stirling, Naghdy, & Potter, 2016). However, the comparison of sensitivity and specificity between methods indicates that no method stands out from the others (da Costa, Rutjes, Mendy, Freund-Heritage, & Vieira, 2012; Gates, Smith, Fisher, & Lamb, 2008). Most methods also have poor predictive power to classify the risk of falling of older adults (Balasubramanian, Boyette, & Wludyka, 2015; Gates et al., 2008). Several studies (Leclerc et al., 2014; Marschollek et al., 2012; Stel et al., 2003) report 'best' sequences of methods to more accurately predict falling, with none remarkably better than the others as well. Interestingly, there is no appraisal on the between-methods agreement of the FRA methods for the prospective screening of older adults as either at high or low risk of falling using published cutoff values. We argue that the lack of such analysis hinders the choice of the FRA methods to be used in the clinic setting.

The primary aim of this study is to describe the agreement between

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fall risk assessment methods to screen the risk of falling of community-dwelling older adults using prospective data and published cut-off values. Secondarily, we evaluate the predictive power of those methods for screening the risk of falling in the same population. Given that falls are multifactorial in etiology (Deandrea et al., 2010; Yamashita et al., 2012), FRA methods might consider distinct aspects of the risk of falling and might have different construct validities (Berg, Wood-Dauphinee, Williams, & Gayton, 1989; El Miedany, El Gaafary, Toth, Palmer, & Ahmed, 2011; Friedman, Munoz, West, Ruben, & Fried, 2002), and no FRA method alone seems preferable (da Costa et al., 2012; Gates et al., 2008), we hypothesize that FRA methods are valid to assess the risk of falling but they mutually disagree for predicting the risk of falling in older adults.

2. Methods

2.1. Ethics

This study followed the Declaration of Helsinki and according to national regulations (Resolution 466/2012) it was approved by the Institutional Ethics Committee prior to its execution (No. 70632017.1.0000.5235). All participants signed a written informed consent form after a complete explanation about the study aims and procedures.

2.2. Study design and report

This is an observational prospective cohort study using a non-probabilistic (convenience) sampling scheme and consecutive admission. Participants were assessed at baseline regarding their clinical status, fall history for the last 6 months and screening for risk of falling using methods as described in the following sections. Follow-up contacts for prospective fall history were made by telephone monthly and personally at 3 and 6 months after admission to this study. All assessments were conducted by the principal investigator as a trained assessor.

Sample size calculation (Rotondi, 2013) showed that at least 32 participants were required to observe a fair-to-good interrater agreement ($\kappa = 0.205$, 95%CI = 0.01 to 0.40) among six methods, each with a two-item response variable (‘high risk’ or ‘low risk’) at 0.3/0.7 probabilities, respectively, to account for the prevalence of falls in this population (Moylan & Binder, 2007).

This study adheres to the Guidelines for Reporting Reliability and Agreement Studies and the guidelines for STrengthening the Reporting of OBservational studies in Epidemiology (Kottner et al., 2011; Vandenbroucke et al., 2014).

2.3. Participants

Community-dwelling residents who seek care in a private physiotherapy clinic were personally and individually contacted by the principal investigator, who explained the study's aims and procedures, as well as the potential risks and benefits of their voluntary participation. Inclusion criteria comprised: ≥ 65 years of age; body mass ≤ 150 kg (by the limit of the posturography device); self-report of no acute musculoskeletal pain; self-report of no neurological or orthopedic conditions that might compromise standing in static or sitting postures; and compliance to attending the study facilities for baseline assessment and follow-up interview. Those eligibility criteria were adopted to exclude participants that could have a fall due to major intrinsic events or overwhelming hazard.

2.4. Clinical assessments

The participants filled a printed form to report their age, sex, body height and mass, physical and clinical conditions, and education level (World Health Organization, 2015). They also answered 22 closed questions in another questionnaire elaborated to identify the main clinical characteristics associated with the risk of falls (El Miedany et al., 2011; Moylan & Binder, 2007; Robinovitch et al., 2013). Briefly, the questionnaire contained questions about retrospective falls, orthosis in use, urinary incontinence, number of drugs in use, hearing loss, and comorbidities more frequently associated with aging such as diabetes, neurological, cardiovascular, and rheumatologic diseases. Stressful life events were investigated using the Stressful Life Events questionnaire regarding the 12 months prior to enrollment in this study (Fink, Kuskowski, & Marshall, 2014; Lopes, Faerstein, & Chor, 2003). Cognitive function was assessed using the Mini-Mental State Examination (Almeida, 1998; Bertolucci, Campacci, & Juliano, 1994; Folstein, Folstein, & McHugh, 1975). Handgrip strength was measured bilaterally using portable Jamar hydraulic hand dynamometer (model J00105, Lafayette Instrument Company, USA) according to the standard recommendations Briefly, the participant sat comfortably with the shoulders in the anatomical position, the elbow of the dominant upper extremity flexed at 90° at the chair’s arm, and the non-dominant hand relaxed over the thigh. The handgrip was adjusted in the dynamometer individually before measurement such that the proximal haste was closer to the body above the phalanges of fingers II-III-IV. Three trials of maximal isometric voluntary contractions were performed lasting 5 s each with a 60-s interval, being the maximal value among trials used as the representative value (Haidar et al., 2004).

2.5. Outcome measures: fall

A fall was defined to the participants as an unexpected event during which they involuntarily come to rest on the ground (World Health Organization, 2007). The circumstance of the fall was classified according to the categories identified in an observational study (Robinovitch et al., 2013). Fall occurrences were annotated in a print fall calendar provided for each participant (Howcroft, Lemaire, Kofman, & McIlroy, 2017). Compliance for filling the calendar was monitored by monthly telephone calls when participants were asked to record on a paper calendar each fall occurring during the monitoring period and their circumstance (Almeida, Valenca, Negreiros, Pinto, & Oliveira-Filho, 2016).

2.6. Outcome measures: risk of falling

The Berg Balance Scale (BBS) quantifies the dynamic postural stability—a person’s ability to control the projection of the body’s center of mass over a base of support while transitioning from a dynamic to a static state (Goldie, Bach, & Evans, 1989). The BBS is composed of 14 items covering functional tasks common to everyday life; each item is categorized on an ordinal scale according to the degree of difficulty: 0 (unable to perform the task) to 4 (performs the task independently) (Berg et al., 1989). The participants were classified as high (0–46 points) or low (47–56 points) risk of falling (sensitivity = 88.2 %, specificity = 76.5 %) (Chiu, Au-Yeung, & Lo, 2003).

Polypharmacy, i.e. the concomitant use of more than five drugs of classes benzodiazepines, antidepressants, antipsychotics and anti-epileptics (Hartikainen, Lönnroos, & Louhivuori, 2007), was used to classified the participants as at high (≥ 5 medications) or low (< 5 medications) risk of falling (sensitivity = 49 %, specificity = 67 %) (Gnjidic et al., 2012).

The Falls Risk Assessment Score (FRAS) is a questionnaire containing five questions that addressed clinical variables that were easily evaluated in the clinical practice. FRAS ranges from 0 to 6.5 points, with higher scores indicating a greater risk of sustaining a fall. The score for each item was: > 1 fall in the last 12 months (‘yes’ = 2); slow walking speed/change in gait (‘yes’ = 1.5); loss of balance (‘yes’ = 1); poor sight (‘yes’ = 1); weak hand grip (‘yes’ = 1); and age (0.02 per year increase from 60 years old). Participants were classified as at high

(> 3.5 points) or low (≤3.5 points) risk of falling (sensitivity = 96.2 %, specificity = 86.0 %) (El Miedany et al., 2011).

The Fall Risk Assessment Tool (FRAT-up) express the probability of falling in 12 months (Cattelani et al., 2015). The FRAT-up questionnaire contains 28 items, with the possibility of leaving blank fields because it embeds prevalence information on individual risk factors (Palumbo, Palmerini, Bandinelli, & Chiari, 2015). The risk factors considered herein to estimate the FRAT-up were: rheumatic disease, Parkinson's disease, use of sedatives, living alone, suffering any pain, use a walking aid, dizziness or unsteadiness last year, urinary incontinence last year, use antiepileptics, history of previous falls, fear of falling, history of previous strokes, sex, use antihypertensives, diabetes, number of drugs used by the participant, age, and hearing impairment. The reported accuracy was 64.2 % (Palumbo et al., 2015). Due to the lack of reported cut-off point, the value of FRAT-up > 0.31 (considering the embedded prevalence for all the factors of the model) as high risk of falling, and low risk of falling otherwise.

The Falls Efficacy Scale (FES) measures the concern for falling when performing activities of daily-living indoors and at the community level (Tinetti, Richman, & Powell, 1990). We used the Portuguese-Brazil version of the FES-I instrument (Yardley et al., 2005), which has both high internal consistency (Cronbach's $\alpha = 0.93$) and reliability (ICC = 0.84 to 0.91). The questionnaire assesses the concern about the possibility of falling when performing 16 activities, each with scores of 1–4. The cut-off point was 23 points or more to discriminate participants at high or low risk of fall (sensitivity = 47 %, specificity = 66 %) (Camargos, Dias, Dias, & Freire, 2010).

Posturography quantifies the static postural stability—a person's ability to control the projection of the body's center of mass over a static base of support (Goldie et al., 1989). Signal acquisition was performed using one Wii Balance Board (WBB) portable force platform (Nintendo Company Limited, Japan) controlled by a custom-built software (LabVIEW 2014, National Instruments, USA). WBB is a valid and reliable instrument to assess static postural balance in elderlies (Clark, Mentiplay, Pua, & Bower, 2018). The protocol followed international recommendations for posturography (Scoppa, Capra, Gallamini, & Shiffer, 2013). The experiment consisted of trials of static postural tasks characterized by feet apart or together and eyes open or closed, summing up four trials. Posturography data was processed for regularization (Goble, Cone, & Fling, 2014) of the sampling frequency, downsampled to 50 Hz, and truncated to 55 s to increase the accuracy of the calculated variables (Audiffren & Contal, 2016). We used the cut-off value for classifying fallers and non-fallers using the Romberg quotient, calculated as the ratio between eyes closed and eyes open values (Van Parys & Njiokiktjien, 1976) of the anteroposterior range of center-of-pressure displacement. The chosen cut-off value discriminates between prospective non-fallers and prospective single fallers without a 6-month fall history using signals acquired from two WBB (high risk: RQ AP range < 1.64); sensitivity = 81.8 %, specificity = 59.6 %) (Howcroft et al., 2017).

2.7. Statistical methods

Primary data was typed into an electronic worksheet for calculation of secondary variables (Microsoft Excel 2016, USA) and then imported to *R* 3.5.1 (R Core Team) for statistical analysis using dedicated packages (Hervé, 2018; Puspendra, Gamer, Jim, Fellows, & Singh, 2014; R Core Team, 2018; Ripley, 2017; Rotondi, 2013; H. Wickham, 2017; Hadley Wickham, 2017; Van De Wiel, 2017). Statistical significance was set at $p < 0.05$.

Data were summarized as median (interquartile range, IQR) or absolute and relative frequencies (%) for numerical or categorical variables. Between-group differences in means (fallers – non-fallers) with respective 95% confidence intervals [95%CI] calculated using the modified Wald's method (Agresti & Coull, 1998) are also shown for each method.

Participants were allocated according to the prospective fall history to either 'non-faller' (no falls within the 6-month follow-up) or 'faller' group (one or more falls within the 6-month follow-up). Between-group comparisons of demographic and clinical variables were performed using Wilcoxon-Man-Whitney (H_0: $\mu_{fallers}$-$\mu_{nonfallers} = 0$) or Fisher's exact test (H_0: $\theta = 1$) for numerical or dichotomous variables, respectively.

Participants were classified as at 'high risk' or 'low risk' of falling using the cut-off values of each method (BBS, polypharmacy, FRAS, FRAT-up, FES, WBB) independently. Contingency tables were thus generated by cross-classification of all participants according to group by risk stratum. Cochran's Q test was used to compare the proportions of participants at high risk according to all FRA methods, followed by the Wilcoxon sign rank as a pairwise post hoc analysis with *p*-values adjusted by the false discovery rate method.

Agreement among all the investigated FRA methods was estimated using the Light's κ coefficient (H_0: $\kappa = 0$) with 95%CI calculated using the bootstrap procedure under the bias-corrected accelerated method with 1000 replications. Pairwise agreement between FRA methods for risk classification was estimated using absolute and relative agreement (%) as well as the Cohen's κ coefficient (H_0: $\kappa = 0$). Agreement was interpreted as poor (< 0.00), slight (0.00 to 0.20), fair (0.21 to 0.40), moderate (0.41 to 0.60), substantial (0.61 to 0.80), or almost perfect (0.81–1.00) (Landis & Koch, 1977). The diagnostic performance of the FRA methods was evaluated by their accuracy, sensitivity, specificity, positive and negative predictive values (Evans, Galen, & Britt, 2005), alongside the modified Wald's 95%CI (Agresti & Coull, 1998).

3. Results

3.1. Participants

Fifty-two participants were enrolled in this study and all completed the six-month follow-up. The participants aged 74 (69–80) years, were mostly female (n = 44, 85 %), and without evidence of dementia with an average of 29 (28–29) points in the MMSE. Most participants reported being regularly engaged in physical activity (n = 42, 81 %) for 2 (2–2) days/week. Handgrip strengths measured for the dominant and non-dominant hands were 20 (16–24) kgf and 20 (18–24) kgf, respectively. They also frequently reported poor sight (n = 47, 90 %) with use of corrective lenses (n = 36, 69 %), and experienced at least one stressful life event in the past 12 months (n = 27, 52 %). Only two (4 %) participants needed a walking assistive device. The most common comorbidity was hypertension (n = 29, 56 %), followed by urinary incontinence (n = 21, 40 %), hearing loss (n = 20, 38 %), and other conditions such as cardiac arrhythmia and type-2 diabetes (n = 8, 15 % each). Between-group comparisons revealed no statistical evidence of differences in baseline assessment (Table 1).

3.2. Falls history, falls circumstances and screening for risk of falling

At baseline assessment, 48 (92 %) participants reported a life history of falls, whereas 15 (29 %) and 12 (23 %) reported a fall in the last 12 and 6 months, respectively. In the prospective follow-up, 9 (17 %) reported at least one fall within 6 months; 6 (67 %) and 3 (33 %) participants reporting one or more falls, respectively (Table 2). Circumstances of falls were trip or stumbling (n = 5, 56 %), incorrect transfer or shift of the body weight (n = 4, 44 %) or slip (n = 1, 11 %). We observed no statistical evidence ($p =$ 0.076 or higher) of differences between fallers and non-fallers regarding all demographic and clinical variables (Table 1).

Between-group comparisons showed no statistical evidence of differences in mean for BBS (-1 point, 95%CI [-7; 4]), FRAS (0.5 points, 95%CI [-0.7; 1.]), FRAT-up (4 %, 95%CI [-37; 45 %]), FES-I (4 points, 95%CI [1; 8]), and posturography (0.04, 95%CI [-0.76; 0.85]). Prospective fall occurrence and high risk of fall as determined by

Table 1
Sample characteristics (n = 52).

	Groups		P-value
	Fallers	Non-fallers	
Sample size, n	9 (17%)	43 (83%)	NT
Age, years	78 (71-85)	74 (69-80)	0.448
Sex, n (%)			
Women	8 (89%)	36 (84%)	1.000
Men	1 (11%)	7 (16%)	
Mini Mental State Exam, score	29 (28-29)	28 (28-29)	0.775
Body height, cm	154 (153-156)	160 (155-165)	0.076
Body mass, kg	63 (57-70)	66 (57-74)	0.508
Body mass index, kg/m^2	25.9 (23.4-27.7)	26.4 (23.1-27.5)	0.997
Physical activity			
Regular practice, n (%)	7 (78%)	35 (81%)	1.000
Frequency, days/week	2 (2-2)	2 (2-3)	0.171
Handgrip strength			
Dominant hand, measured, kgf	20 (20-22)	20 (16-24)	0.899
Non-dominant hand, measured, kgf	22 (18-24)	20 (18-24)	0.909
Anamnesis, n (%)			
Poor sight	7 (78%)	40 (93%)	0.202
Corrective lenses	5 (56%)	31 (72%)	0.431
Stressful life events	4 (44%)	23 (53%)	0.722
Walking device	1 (11%)	1 (2%)	0.319
Comorbidities, n (%)			
Hypertension	6 (67%)	23 (53%)	0.714
Urinary incontinence	5 (56%)	16 (37%)	0.457
Hearing loss	2 (22%)	18 (42%)	0.454
Cardiac arrhythmia	2 (22%)	6 (14%)	0.615
Diabetes	2 (22%)	6 (14%)	0.615

NT: not tested.
Groups were classified according to the prospective fall occurrences.

Table 2
Fall history and summary results of the fall risk assessment methods (n = 52).

	Groups		P-value
	Fallers	Non-fallers	
Fall history, n (%)			
Life history of previous fall(s)	9 (100%)	39 (91%)	1.000
History of previous fall(s) in the last 12 months	3 (33%)	12 (28%)	0.706
History of one fall in the last 6 months	3 (33%)	9 (21%)	0.415
Berg Balance Scale, score	55 (53-56)	55 (54-56)	0.319
High risk of falling, n (%)	1 (11%)	1 (2%)	0.319
Low risk of falling, n (%)	8 (89%)	42 (98%)	
Polypharmacy, n (%)			
High risk of falling, n (%)	8 (89%)	16 (37%)	**0.008**
Low risk of falling, n (%)	1 (11%)	27 (63%)	
Fall Risk Assessment Score, score	3.8 (3.1-4.1)	2.8 (1.3-3.9)	0.238
High risk of falling, n (%)	6 (67%)	19 (44%)	0.284
Low risk of falling, n (%)	3 (33%)	24 (56%)	
Fall Risk Assessment Tool, %	38 (28-39)	31 (24-37)	0.128
High risk of falling, n (%)	6 (67%)	21 (49%)	0.469
Low risk of falling, n (%)	3 (33%)	22 (51%)	
Falls Efficacy Scale, score	25 (22-36)	22 (20-24)	0.111
High risk of falling, n (%)	6 (67%)	14 (33%)	0.071
Low risk of falling, n (%)	3 (33%)	29 (67%)	
Posturography, AP Range Romberg Quotient	1.19 (0.95-1.44)	1.11 (0.84-1.34)	0.617
High risk of falling, n (%)	7 (78%)	36 (84%)	0.645
Low risk of falling, n (%)	2 (22%)	7 (16%)	

Groups were classified according to the prospective fall occurrences.

polypharmacy were significantly associated ($p = 0.008$). No association though was observed between prospective fall occurrence and risk of falling using BBS ($p = 0.319$), FRAS ($p = 0.284$), FRAT-up ($p = 0.469$), FES ($p = 0.071$), or posturography ($p = 0.645$) (Table 2).

Table 3
Agreement between fall risk assessment methods of classification of risk of falling (n = 52).

	Berg Balance Scale	Polypharmacy	Falls Risk Assessment Score	Fall Risk Assessment Tool	Falls Efficacy Scale
Polypharmacy	53.8% κ = 0.006 p = 0.911	NT	NT	NT	NT
Falls Risk Assessment Score	55.8% κ = 0.083 p = 0.134	51.9% κ = 0.036 p = 0.797	NT	NT	NT
Fall Risk Assessment Tool	51.9% κ = 0.071 p = 0.165	59.6% κ = 0.195 p = 0.158	**73.1% κ = 0.462 p = 0.001**	NT	NT
Falls Efficacy Scale	57.7% κ = -0.075 p = 0.254	61.5% κ = 0.217 p = 0.113	63.5% κ = 0.263 p = 0.053	**67.3% κ = 0.352 p = 0.008**	NT
Posturography	17.3% κ = -0.031 p = 0.213	51.9% κ = 0.085 p = 0.396	38.5% κ = -0.201 p = 0.050	42.3% κ = -0.184 p = 0.088	32.7% κ = -0.170 p = 0.056

NT: not tested.
Groups were classified according to the prospective fall occurrences.

Table 4
Confusion matrix for the diagnostic performance of fall risk assessment methods (n = 52).

Fall Risk Assessment Method	Accuracy (95%CI)	Sensitivity (95%CI)	Specificity (95%CI)	Predictive Value + (95%CI)	Predictive Value - (95%CI)
Berg Balance Scale	83% (70-91)	11% (0-46)	98% (87-100)	50% (10-90)	84% (71-92)
Polypharmacy	67% (54-78)	89% (54-100)	63% (48-76)	33% (18-53)	96% (81-100)
Falls Efficacy Scale	67% (54-78)	67% (35-88)	67% (52-80)	30% (14-52)	91% (75-97)
Falls Risk Assessment Score	58% (44-70)	67% (35-88)	56% (41-70)	24% (11-44)	89% (71-97)
Fall Risk Assessment Tool	54% (41-67)	67% (35-88)	51% (37-65)	22% (10-41)	88% (69-97)
Posturography	27% (17-40)	78% (44-94)	16% (8-30)	16% (8-30)	78% (44-94)

CI: confidence interval.
Groups were classified according to the prospective fall occurrences.

3.3. Comparison, agreement and accuracy of fall risk assessment methods

Cochran's test showed different proportions of participants classified as at high risk of falling among all FRA methods ($Q = 69.560$, $p < 0.001$). Post hoc pairwise analyses in Table 3 showed statistical evidence of different proportions of participants at high risk of falling using either BBS or posturography compared with all other methods ($p = 0.009$ or lower). All other comparisons showed no statistical evidence of differences in proportions ($p = 0.215$ or higher).

A slightly better-then-chance agreement was estimated between all six FRA methods (Light's κ = 0.074, 95%CI [0.021; 0.142]). Pairwise analyses of the FRA methods shown in Table 3 revealed agreements ranging from moderate (FRAS vs. FRAT-up: percent agreement: 73.1 %, Cohen's κ = 0.462, $p = 0.001$) to poor (FRAS vs. Posturography: percent agreement: 38.5 %, Cohen's κ = -0.201, $p = 0.050$).

Table 4 shows the summary data on the predictive power of the FRA methods. BBS was the most accurate method to screen a faller (accuracy = 83 %, 95%CI [70; 91]), followed by polypharmacy, FES, FRAS, FRAT-up, and WBB (accuracy 27 %, 95%CI [17; 40]). BBS also showed the highest positive predictive value (50 %, 95%CI [10; 90 %]), whereas polypharmacy showed the highest negative predictive value (96 %, 95%CI [81; 100]).

4. Discussion

We described the agreement between fall risk assessment methods to screen the risk of falling of community-dwelling older adults using prospective data and published cut-off values. Secondarily, we evaluated the predictive power of those methods for screening the risk of falling in the same population. The major finding of this study is that the methods investigated herein—BBS, polypharmacy, FRAS, FRAT-up, FES, and posturography—with their respective cutoff values disagree for screening the risk of falling in older adults. Clinicians should be aware that they not only yielded different proportions of participants at high-low risk of falling; they were also disagreeing in such screening. Even in a pairwise analysis, those methods moderately agree at best. These findings contrast with the observed accuracy and related probabilities for screening the risk of falling, suggesting that most of the methods investigated are valid tools for the screening of prospective falls in this population. Altogether, those findings support the existent evidence regarding the validity of those methods but also our reinforces our hypothesis questioning their agreement for screening the risk of falling in older adults.

The highest agreement was observed between FRAS and FRAT-up, even though both methods assess prospective falls within 12 months and not 6 months as per our study design. This can be explained by the fact that 3 of the 5 questions of the FRAS method are present in the FRAT-up (history of previous falls, gait aspects, the perception of balance). This is an interesting finding because the FRAS method does not address issues such as comorbidities, polypharmacy and psychological status of the patient—important risk factors (Deandrea et al., 2010; Yamashita et al., 2012) for falling in older adults. Conversely, the worst agreement was observed between FRAS and posturography. While the reasoning behind this 'worst-than-chance' agreement is uncertain, we speculate that the questions addressed by FRAS are not informative of the underlying strategies for stabilizing the body's static posture.

The most accurate FRA method for screening the risk of falling was BBS, the highest positive predictive value, whereas the remaining FRA methods showed poor screening capability. It was an expected outcome because most of the FRA methods have poor discrimination between fallers and non-fallers (Gates et al., 2008). These results are also in agreement with the report that discrimination power between fallers and non-fallers using functional mobility tests and balance assessments are poor but slightly better to discriminate the recurrent fallers from those with fewer or no falls (Balasubramanian et al., 2015). The BBS stood out from the others, although the FES, FRAS, and FRAT-up presented similar accuracies to those found in the literature (Camargos et al., 2010; Gates et al., 2008; Palumbo et al., 2015).

Conversely, the less accurate method was posturography. Posturography using the WBB has relatively large measurement errors (2 − 6 mm) as compared to laboratory-grade posturography devices (Scoppa et al., 2013), but it is arguably acceptable for frequent, longitudinal monitoring in a large-scale population (Leach, Mancini, Peterka, Hayes, & Horak, 2014). Our findings do not recommend using the Romberg quotient of the anteroposterior range and respective cut-off (Howcroft et al., 2017) for classifying fallers and non-fallers. Of notice, posturography was assessed herein with two adaptations from a previous study (Howcroft et al., 2017) that could challenge our findings. First, the calculation of the Romberg quotient using one rather than two WBB; because the center of pressure signals acquired from two force plates are summarized as a single signal by simple linear combination (Exell, Kerwin, Irwin, & Gittoes, 2011; MacRae, Critchley, Lewis, & Shortland, 2018) before calculating the Romberg Quotient the expected difference is minimal if any. Second, the application of a cut-off score designed to discriminates between prospective non-fallers and prospective single fallers without a 6-month fall history. Considering that WBB was found valid and reliable to assess static postural balance in older adults (Clark et al., 2018), future studies should evaluate whether other posturography variables and/or cut-off values have better screening performances.

Our sample was composed by highly functional, community-dwelling older adults. It is worth noticing that the enrolled sample received an individualized physiotherapy intervention prescribed pragmatically that, although not aiming to improve postural stability, could have reduced both the risk of falling and rate of falls as reported in previous studies (Hill & Schwarz, 2004; Sherrington et al., 2017; Tricco et al., 2017). This fact helps to explain the lack of difference of FRA methods between participants grouped as faller and non-fallers as in another study (Santos, Souza, Virtuoso, Tavares, & Mazo, 2011) analyzing the predictive values for the risk of falling in physically active or inactive older adults using the BBS. Also, sudden emotional stress had the potential to trigger falls among autonomous older adults in retrospective studies (Möller et al., 2009; Peterson et al., 2000), which was not confirmed herein using prospective fall occurrence. Handgrip strength is a predictor of overall body strength and functional performance in different groups of individuals and a risk factor for falls (Lloyd et al., 2009), and also was not different between groups. Finally, none of the falls reported by the enrolled participants were due to cardiovascular, neurologic or another hazard condition, which might be explained by the adopted exclusion criteria. Collectively, these results suggest that our results should be extrapolated with cautions to older adults with poor health status.

There are some limitations of this study worth noting. First, our follow-up time might be considered short for screening, which could result in a low incidence of falls. Second, the nonprobabilistic sampling scheme adopted could modify both the fall risk and occurrence during follow-up because patients were recruited at a private practice setting and underwent physiotherapy intervention during the follow-up. However, we observed an incidence of falls similar to the literature (Moylan & Binder, 2007), which increases our confidence that such bias was minimized if any. Finally, our sample size was estimated for investigating the agreement between FRA methods, which also explains the low statistical power to detect statistical significance for small differences for the secondary outcomes (between-group comparisons and screening accuracies) and could affect the estimates of sensitivity, specificity, positive and negative predictive values. In contrast, this study has some strengths. First, the adopted follow-up guaranteed compliance for completing the study and reporting the prospective fall occurrence. Moreover, by using FRA methods based on one question (polypharmacy), clinical questionnaires (FRAS, FRAT-up, FES), performance-based questionnaires (BBS) and devices (WBB) we covered a variety of FRA methods used for management (Hill & Schwarz, 2004; Sherrington et al., 2017; Tricco et al., 2017) of the risk of falling.

To the best of our knowledge, we believe this study helps to fill an existing gap for the rehabilitation expert by providing evidence regarding the agreement of the FRA methods for screening the risk of falling in community-dwelling older adults. Based on our findings, further research is needed to test the extent to what other FRA methods have a higher agreement for screening risk of falling. We hypothesize that considering agreement as an information systematically being shared between methods (Watson & Petrie, 2010), the combination of FRA methods that even though have a low agreement—e.g. using the ‘believe the positive’ strategy (Pepe & Thompson, 2000)—they might further improve the screening of risk of falling in older adults.

5. Conclusions

We found both global and pairwise agreement levels that question the agreement of BBS, polypharmacy, FRAS, FRAT-up, FES, and posturography for screening risk of falling in community-dwelling older adults.

Conflict of Interests

None to declare.

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CRediT authorship contribution statement

Michele Menezes: Methodology, Formal analysis, Investigation, Data curation, Writing - original draft, Writing - review & editing. **Ney Armando de Mello Meziat-Filho:** Conceptualization, Methodology, Writing - review & editing. **Camila Santos Araújo:** Investigation, Data curation, Writing - original draft, Writing - review & editing. **Thiago Lemos:** Conceptualization, Methodology, Writing - review & editing. **Arthur Sá Ferreira:** Conceptualization, Methodology, Software, Formal analysis, Resources, Writing - original draft, Writing - review & editing, Visualization, Supervision, Project administration, Funding acquisition.

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