STRATIFYING RISK OF FALLS IN COMMUNITY-DWELLING ELDERLY ADULTS THROUGH A SIMPLE TOOL

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ABSTRACT

Purpose. Falls are among the main disabling events for elderly adults and the identification of old people prone to falls enables the development of preventive and rehabilitative strategies. This study aimed to develop a simple tool, based on easily obtained variables (anthropometric measurements, motor performance tests and sociodemographic characteristics), to early identify community-dwelling old people prone to falls. **Methods.** The population-based household study was conducted among 316 elders (≥ 60 years old) of both sexes, living in the urban area of Lafaiete Coutinho in Brazil. History of falls in the previous 12 months (dependent variable), sociodemographic characteristics, anthropometric measurements and motor performance tests results (explanatory variables) were recorded, and a multivariate logistic regression was applied to identify the association between the explanatory variables and the history of falls. Fall probability for each elderly adult was calculated from the logistic regression parameters, and the predictive power of the final model and the cutoff for higher propensity to fall were evaluated on the basis of the receiver operating characteristic curve. **Results.** The prevalence of falls was 25.8% and the final model was influenced by the variables of sex (female) and poor performance in the balance test. The estimated probability model predicted approximately 66.5% (95% CI, 61–72%) of the falls. The sensitivity and specificity were 58 and 70%, respectively. **Conclusions.** We conclude that there is a high prevalence of falls among the studied elderly individuals, and the proposed method allowed to construct a simple tool for screening old adults prone to fall.

Key words: postural balance, aging, logistic regression

Introduction

Aging, a natural process in human life, is influenced by genetic factors, lifestyle and environmental aspects [1]. Multiple morphological and functional changes are observed during the aging process, and may result in a progressive decrease in functional capacity [2].

Impairment in balance control is commonly present during aging, and has been associated with decrements in the integration of vestibular, visual and proprioceptive systems, as well as impairments in descendent motor commands, neuromuscular responses, muscle strength and reaction time, making elderly people prone to falls [3].

Moreover, falls have been pointed as a major cause of morbidity and mortality in older adults [4], accounting for approximately 11% of all deaths from unintentional injury worldwide [5]. It is assumed that approximately 1/3 of the community-dwelling old people fall and half of them experience multiple episodes each year [6].

The injuries subsequent to a fall episode are considered an important public health problem [7], producing high costs to the health systems worldwide. Previous studies have pointed the variables of sex (i.e. female) [8], advanced age [4], low schooling [9, 10], family arrangement (i.e. living alone) [11, 12], race (i.e. white) [13, 14], extreme values of body mass index (BMI) [15], reduced muscle mass [16], reduced lower limb strength [17], low mobility [18], decreased flexibility [19] and impaired balance [20] as promising predictors of falls in the elderly.

Interestingly, it has been postulated that a considerable proportion of falls are likely to be reduced through preventive and rehabilitative strategies [21], which may account for a reduction of 30–40% in the recurrence of fall events after a period of one year [22]. This evidence highlights the need to increase the knowledge about factors significantly associated with the risk of falling in the elderly to better stratify old people prone to falls and, thus, develop intervention strategies.

Previous surveys conducted in developed countries aimed at developing predictive models of falls [12, 13]. They applied multiple logistic regression analysis models to identify old people prone to falls, on the basis of sociodemographic, anthropometric and physical or motor performance. This approach could be useful and save time and money by allowing early identification of the target population (i.e. old people prone to falls).

In developing countries, as Brazil, some studies [23, 24] have been carried out, including the aforementioned variables as predictors of falls, but they did not employ a multi-

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ple analysis approach, verifying the association between fall history and each predictive variable singly. To the authors' knowledge, there are no population surveys conducted in developing countries that would aim to create a predictive statistical model for falls in old people with these variables together.

Therefore, the aim of this study was to develop a simple tool, making use of a multiple logistic regression analysis with the sociodemographic characteristics, anthropometric measurements and motor performance test as predictive variables, to screen for community-dwelling elderly adults prone to falls.

Material and methods

Participants

The study was based on data from an epidemiological cross-sectional population-based survey called 'Nutritional status, risk behaviors, and health conditions of the elderly of Lafaiete Coutinho, Bahia, Brazil.' Details about the location and study population, as well as data collection have been published previously [25]. Briefly, a census was conducted in Lafaiete Coutinho (January, 2011) to screen all elderly adults (≥ 60 years). Data from the Family Health Strategy, a primary health care program that covers all the county, were used to locate the residences; then, domiciliary visits were carried out. All seniors residing in urban areas ($n = 355$) were contacted. Out of the 355 individuals who comprised the study population, 316 (89%) participated in the study: 17 refusals were recorded (4.8%) and 22 (6.2%) individuals were not located after three visits on alternate days, and were considered sample loss. The study was conducted in accordance with the Declaration of Helsinki, and the Local Ethics Committee approved the involved procedures. Prior to data collection, the volunteers signed the consent form.

Variables

Fall history (dependent variable)

The dichotomous dependent variable for the statistical analysis was the reported fall history, which was obtained through the question 'Have you had any falls in the past 12 months?' (1 = yes; 0 = no).

Explanatory variables

The variables chosen as potential explanatory ones were grouped into: sociodemographic characteristics, anthropometric measurements and motor performance test.

The variables of sex (1 = female; 0 = male), age (continuous data), family arrangement (1 = living alone; 0 = living with someone), schooling (1 = illiterate; 0 = literate) and race (1 = white; 0 = all others) were used as sociodemographic characteristics.

BMI, corrected arm muscle area (cAMA), which was calculated with the use of the arm circumference (AC) and triceps skinfold thickness (TST) {cAMA = [(AR – ϖ × TST)^2 / 4 × ϖ] – 10 for men; cAMA = [(AR – ϖ × TST)^2 / 4 × ϖ] – 6.5 for women}, as proposed by Heymsfield et al. [26], and calf circumference, obtained as indicated by Callaway et al. [27], were applied as anthropometric measurements.

The variables involving the motor performance tests were: (1) Chair Stand Test; (2) Timed Up & Go (TUG) test; (3) picking a pen up from the floor; (4) balance test battery.

The Chair Stand Test was used as a measure of lower limb strength. It consists in measuring the time to rise from a chair and return to the seated position 5 times with the arms crossed in front of the chest. To categorize this variable, the time spent to complete the task was encoded according to percentiles, as proposed by Barbosa et al. [28]. Data were represented as score = 0 (unable) for subjects who were unable or unwilling to carry out the task, score = 1 (poor) for subjects who performed the task above percentile 75% (> 17 s), score = 2 (medium) for subjects who completed the task above percentile 25% and equal to or below percentile 75% (from > 10 to ≤ 17 s), and score = 3 (good) for those who accomplished the task at the level equal to or above percentile 25% (≤ 10 s).

The TUG test was used to evaluate the functional mobility and gait speed. The participants were asked to rise from a chair, walk 2.44 m at their normal and comfortable speed, and return to the chair. The time spent to complete the task was recorded and the results were encoded according to percentiles, as indicated in the Chair Stand Test.

To check the lower limb strength, flexibility (lower limb and back muscles), coordination and balance, the test of picking a pen up from the floor was used. The participants were instructed to remain upright and, when informed, to bend down, pick up a pencil placed on the floor 30 cm in front of the tip of their feet, and return to the starting position with the pencil in their hand [29]. Individuals were considered capable of performing the test when they could complete it without any support within the time equal to or less than 30 s. The classification according to Reuben and Siu [30] (adapted) was applied to assess the performance. Data were encoded as score = 0 (unable) for subjects who were unable or unwilling to carry out the task, score = 1 (poor) for subjects who performed the task above percentile 75% (> 3 s), score = 2 (medium) for subjects who completed the task above percentile 25% and equal to or below percentile 75% (from > 1 to ≤ 3 s), and score = 3 (good) for those who accomplished the task at the level equal to or above percentile 25% (≤ 1 s).

Balance was evaluated with a battery of four balance tests in which the participants were requested to maintain a required posture for 10 s: (1) standing with both

feet together and touching each other (side-by-side stand); (2) standing with the heel of one foot directly in front of the toes of the other foot (full tandem stand); (3) standing on the right leg (one-leg stand); (4) standing on the left leg (one-leg stand). To allow for a unique result, the scores proposed by Barbosa et al. [28] were employed: score = 0 (unable) for subjects who were unable to perform any of the tasks within 10 s; score = 1 (poor) for subjects who could hold a side-by-side standing position for 10 s but were unable to carry out any other task; score = 2 (medium) for subjects who could hold a side-by-side standing position and full tandem stand for 10 s each, but were unable to complete a one-leg stand (right and left); score = 3 (good) for those who could hold a one-leg standing position (right, left or both).

Statistical procedures

The descriptive analyses were carried out on the basis of absolute and relative frequencies, mean and standard deviation. The association among fall history and the explanatory variables was tested by multiple logistic regression with the use of the 'Backward LR' method. The group that did not report falls was defined as the reference category.

The multiple logistic regression was preceded by an univariate analysis to select the explanatory variables. Comparisons between groups (i.e. participants with and without fall history) employed the chi-square test for categorical variables and the t-Student test for continuous variables, for each variable of interest. Variables that achieved a significance level of $p < 0.1$ were included in the multivariate analysis, as proposed by Conover [31].

Adjusted prevalence ratios (PR) and their respective 95% confidence intervals (95% CI) were obtained. On the basis of the group of variables included in the final model, the logistic probability of fall was calculated for each participant, allowing to estimate the predictive power from the final model. The predictive power, as well as the cutoff point that indicates a major propensity to fall, were obtained from the parameters of the receiver operating characteristic (ROC) curve: area under the curve (AUC), sensitivity and specificity.

For the multivariate analysis, the significance level adopted was $p \leq 0.05$. Data were analysed with the SPSS® 21.0 and MedCalc software (version 9.1.0.1, 2006).

Results

Out of the 316 elders, 173 were women (54.7%) and 143 men (45.3%). The participants were aged 74.2 ± 9.7 years (60–105 years). Table 1 shows the sociodemographic characteristics and physical performance, while table 2 presents the anthropometric profile of the studied population.

Table 1. Descriptive analysis of the studied qualitative variables

Variables	% of answers	n	%
Sex	100		
Male		143	45.3
Female		173	54.7
Schooling (ability to read and write)	100		
No		211	66.8
Yes		105	33.2
Family arrangement	100		
Living alone		52	16.5
Living with someone		264	83.5
Race / skin colour	95.9		
White		64	21.1
Non-white		239	78.9
Chair Stand Test	99.4		
Unable		45	14.3
Poor		64	20.4
Medium		136	43.3
Good		69	22.0
Picking a pen up from the floor	90.5		
Unable		26	9.1
Poor		45	15.7
Medium		111	38.8
Good		104	36.4
TUG test	95.9		
Unable		26	8.6
Poor		52	17.2
Medium		76	25.1
Good		149	49.2
Balance test battery	99.4		
Unable		28	8.9
Poor		67	21.3
Medium		81	25.8
Good		138	43.9

Table 2. Descriptive analysis of the studied quantitative variables

Variables	% of answers	Mean	SD	Min–Max
Age (years)	99.7	74.2	9.7	60.0–105.0
BMI (kg/m^2)	95.3	24.5	4.6	13.6–41.2
cAMA (cm^2)	97.5	32.9	9.0	9.7–56.1
Calf circumference (cm)	97.5	33.2	3.6	22.1–43.0

BMI – body mass index
cAMA – corrected arm muscle area

The prevalence of falls in the studied population was 25.8%, and after the univariate analysis, only the variables of family arrangement, sex, cAMA, Chair Stand test, the test of picking a pen up from the floor, the TUG test and the balance test battery reached the inclusion criteria ($p < 0.10$) for the multiple logistic regression model. Table 3 shows the variables included in the model with the respective levels of significance achieved.

Table 3. Variables included in the multiple logistic regression model with their significance levels obtained in the univariate tests

Variable	P value
Age**	0.553
Schooling*	0.745
Race / skin colour*	0.522
Family arrangement*	0.01***
Sex*	< 0.01***
cAMA**	0.04***
BMI**	0.185
Calf circumference**	0.171
Chair Stand Test*	< 0.01***
Picking a pen up from the floor*	< 0.01***
TUG test*	< 0.01***
Balance test battery*	< 0.01***

* chi-square test
** t-Student test
*** significant at $p < 0,10$
cAMA – corrected arm muscle area,
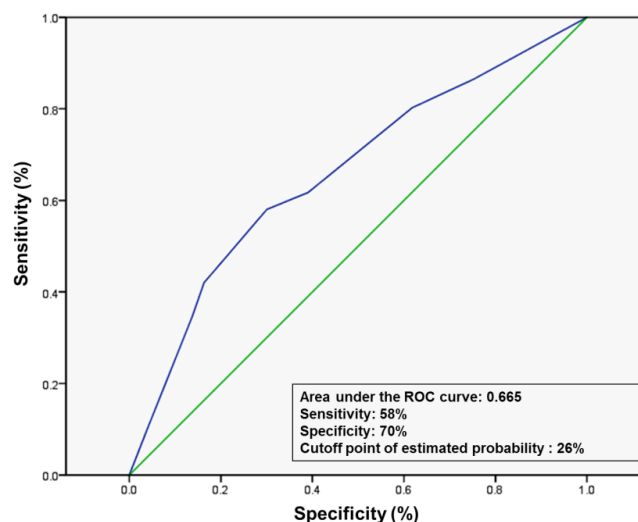BMI – body mass index, TUG – Timed Up & Go

Figure 1. The ROC curve of the estimated probabilities of falls in the studied community-dwelling elderly adults

Table 4. Regression coefficients, adjusted odds ratios (OR), 95% confidence intervals (CI) of the OR, and the *p* values of the variables included in the prediction model

Variable	Regression coefficient	P value	Adjusted odds ratio	95% CI odds ratio
Sex	0.740	0.01	2.10	1.18–3.74
Balance test battery	–0.444	0.01	0.64	0.49–0.84
Constant	–0.596	–	–	–

Table 5. Estimated probabilities of a fall event, based on the final model variables

Sex	Balance test battery (score)	Fall probability (%)
Female	0	54%
Male		36%
Female	1	43%
Male		26%
Female	2	32%
Male		18%
Female	3	23%
Male		13%

The final model, obtained in the multivariate analysis, was composed of the variables of sex and balance test battery. Table 4 presents the regression coefficients and the adjusted odds ratios for the variables in the final model. Female sex was directly associated with the fall occurrence, as shown by the regression coefficient, while the performance in the balance tests was inversely associated, which is verified by the negative value of the regression coefficient. From the final model parameters it is possible to infer that elderly women (adjusted OR, 2.10; 95% CI, 1.18–3.74) are prone to falls, and a good performance in the balance tests (adjusted OR, 0.64; 95% CI, 0.49–0.84) is a protective factor to falls in old adults.

Figure 1 shows the ROC curve of the estimated probabilities of a fall event in the community-dwelling elderly adults from the studied population. The AUC indicates that the model estimated probabilities can predict ca. 66.5% (95% CI, 61–72%) of the events. Additionally, the estimated sensitivity was 58%, specificity equalled 70%, and the cutoff probability estimated by the final model was 26%.

On the basis of the results of the applied statistical procedures, a screening tool was created that allows to individually identify elderly adults more prone to fall events. As shown in Table 5, it can be estimated that e.g. an old woman who scored 3 in the balance test battery represents a fall probability of 23%, i.e. below the cutoff point obtained by the ROC curve. In contrast, elderly women with a worse performance in the balance test (scores 2, 1 or 0 in the balance test battery) would present fall probabilities of 32, 43 and 54%, respectively, which is higher than the cutoff point established in the

ROC curve, indicating an imminent risk of falling. Old men, with scores 0 or 1 in the balance test battery, may have a 36 and 26% probability of fall, respectively, which denotes an imminent risk of falling, while those scoring 2 or 3 have no imminent risk.

Discussion

The main result of this study was an elevated prevalence of fall events (25.8%) and a predictive model generated to screen the risk of falls in community-dwelling old adults, which included the variables of sex (female) and poor performance in the balance test battery.

Comparing the established prevalence with other studies, conducted in different regions of Brazil, one can observe that the prevalence is similar [32–34], and women are more prone to falls than men [33, 35–37].

Bongue et al. [36] generated a predictive model for fall events in elders that included the variables of sex, living alone, psychoactive drug use, osteoarthritis, previous falls and the one-leg balance test. In the mentioned study, the screening tool AUC of the ROC curve was 0.70. Despite the methodological differences, our results propose a simpler screening tool, which is composed only of sex (female) and the score of a simple balance test battery, and reached a very close predictive capacity (the AUC of 0.66). Moreover, the results of Bongue et al. [36] were obtained in a population from a developed country, while our study was performed among elderly adults living in a developing country.

Some hypotheses are raised in the literature to explain the female propensity to fall. Fried et al. [38] pointed out the female fragility as one of the causes of the higher incidence of falls in women. According to the authors, this fact is owing to the faster reduction of lean body mass (i.e. muscle and bone mass) and muscle strength, which begins around 40 years of age, making women more susceptible to falls as compared with men. In addition, Perracini and Ramos [39] proposed that the high prevalence of chronic diseases in women and the greater frequency of domestic activities could be factors increasing the number of fall events in elderly women.

Our results confirmed the association between poor balance control and the fall risk. The applied balance test battery includes four of the most frequently used and reported clinical balance tests [40, 41], and therefore it may be applied without special equipment and by any health professional with minimal training.

It is known that the balance control and compensatory postural responses, which contribute to avoiding falls, are affected during the aging process [20]. The balance test battery allows evaluating the balance control and compensatory postural responses, since it exposes the elders to four different situations where the difficulty is progressively increased: standing with a small support base (i.e. feet together), tandem stand, and one-leg support stand (right/left). Additionally, the most important feature of the suggested battery test is that it allows to generate a score associated with a graded performance, with 4 levels, ranging from 0 to 3.

This feature could justify the maintenance of this variable in the final predictive model, allowing to generate a simple but promising predictive paradigm. From this predictive model it is possible to infer that old men scoring 0 or 1, as well as old women scoring 0, 1 or 2 are prone to falls and should be included in interventional programs to prevent falls.

The estimates of fall probabilities for each elderly adult, in accordance with the variables of the final model generated in the study, could be used to refer old people with a high risk profile to preventive programs in order to avoid the increase in the number of falls. Screening for the elderly prone to falls is considered to be of great importance, since the identification of old people at high risk of falling would theoretically allow the development of fall-prevention interventions to support those most likely to benefit from them [42].

Conclusions

Falls belong to the major health problems of elderly people, and our results showed a high prevalence of falls in the studied population. A promising predictive model was generated, which includes only the variables of sex and performance in the balance test battery.

Further studies, with longitudinal design, should apply this simple and low-cost tool for screening old adults prone to fall, confirming or refuting the usefulness of the model.

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