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Epidemiology

Predictive factors for falls and protective effect of group exercise in older adults: a prospective evaluation

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Abstract - Aim: This study aimed to assess the predictive value of well-known risk factors for falling in older adults by prospectively evaluating the occurrence of fall episodes on those who joined a group-oriented exercising routine compared to older people without the exercise routine. **Methods:** The balance parameters of 75 older adults were assessed using a force platform along with the history of previous falls, and the presence of diabetes. A subsample (n = 58) performed a group exercising routine 2 to 3 times per week for 1 year. They were followed-up concerning the occurrence of falls episodes. **Results:** The binary logistic regression analysis retrieved a model including the presence of diabetes (OR = 8.78), previous history of falls (OR = 4.90) and the ML excursion (OR = 0.43) as predictive factors of prospective falls accurately (Sn = 0.948). The exercising routine was protective against future episodes of falls (OR = 4.84). **Conclusion:** The regression model was able to accurately predict those older adults under the risk of prospective falls. Group exercising was able to protect older people from future falls.

Keywords: aging, exercise therapy, accident prevention, prognosis, frail elderly.

Introduction

Falls are a global public health problem. According with World Health Organization (WHO) falls represent the second leading cause of unintentional injury death and are most prevalent in adults aged over 60 years[1]. In the world falls incidence range from 27-35%[2-5]. In Brazil twelve-month falls prevalence is 27%, been women and individuals aged over 80 years the groups with higher prevalence[5]. Fall-related hospitalization costed to Brazilian government over BRL 2 million, between 2000 and 2020[6].

Falls can have physical and emotional impacts in older adults, impairing quality of life and physical performance, and increasing rates of disability and mortality[7,8]. The major risk factors for falls are currently well-described (e. g: dangerous environment, slippery or uneven ground, history of previous falls, diabetes, balance and strength impairments)[9,10]. However many of these factors were described by cross-sectional designs studies that classified older adults in fallers and non-fallers, considering previous falls as the between-group factor[11-14].

Physical exercises have been proposed as strategy to improve physical performance and a protective factor for falls[15-17]. During physical exercise active and resisted movements challenge neuromuscular system which counteracted the frailty common in older adults[2,18,19]. Several types of exercises have been proposed as viable and easy-to-perform ways to prevent fall, including group interventions[20-23].

Group exercises interventions are suggested to improve balance and mobility in older adults[20]. In addition, these interventions can promote socialization which improve exercises adherence and positively impacts emotional function[23]. Group exercises interventions are also supposed to provide economic benefits, as a single instructor could prescribe and control the exercise protocol for multiple participants.

Despite the advantages and attractiveness of group exercise interventions, evidence suggests that individually exercises might be more effective to falls prevention[18]. In this sense, research investigating the factors associated to fall prediction in older adults who adhere to group exercises intervention could provide insightful panoramic overview about any changes induced by the group exercise.

This study aims to assess the predictive value of well-known risk factors for falls in older adults by a prospective evaluation and investigate the protective value of a group-oriented exercising routine. The current hypothesis is that some classic risk factor for falls would not have the same weight after a year of group-oriented exercise protocol, and others would play a more determinant role to accurately predict falls.

Materials and methods

This prospective cohort study conducted in a private clinic located in the city of Governador Valadares, Minas Gerais, Brazil. The study was conducted in accordance with the Declaration of Helsinki, and was approved by the ethics committee of Federal University of Juiz de Fora (CAAE: 59862316.7.0000.5147). Prior to undergoing any evaluation all participants signed an informed consent form

Participants

The sample was recruited by public invitation through folders and personal contacts. The inclusion criteria were to be physically independent (level 3 or 4 on Functional Status)[24], age ≥ 60 years old and cognitively able to understand the experimental procedures (score > 21 on the Mini-Mental State Examination for people with low education)[25]. Exclusion criteria were: restrictive cardiovascular disease, unstable proliferative retinopathy, end-stage renal disease, uncontrolled hypertension. All participants were free of any knee or hip injury which could affect their balance and cleared from medication that could cause dizziness.

Equipment and procedure

Assessment of the anthropometric variables (weight and height) were done using a stadiometer and a calibrated digital scale. The BTrackS Balance Plate (Balance Tracking System, San Diego, CA, USA) was used to balance assessment. This device consists of a force platform (40 × 60, sampling frequency of 25 Hz) with four implanted strain gauges that determine the center-of-pression (COP) excursion distance. This equipment accuracy/precision was previously tested[26].

For balance evaluation were conducted four 20 s trails. During each trail participants were asked to stand on the BTrackS Balance Plate with their eyes closed, hands on their hips, and feet placed shoulder-width apart. The first trial was for familiarization and was discarded for analysis. Trials were conducted in a closed room to reduce noise and disturbances. Participants were monitored by the evaluator during all trials to avoid a fall episode. The balance test was performed before the group-oriented exercise protocol described below.

After balance tests, the following parameters were offline extracted: path length (total sway length in cm); mean velocity (path length divided by trial duration in cm/s); mean distance from the center (the average distance from the center of the total path in cm); 95% confidence interval ellipse area (the smallest ellipse fitting 95% of Center of Pressure [COP] data in cm2); mean frequency (the average number of loops to cover COP data in Hz); medial-lateral (ML) excursion (the maximal minus the minimal COP data points in ML direction in cm); anterior-posterior (AP) excursion (the maximal minus the minimal COP data points in the AP direction in cm).

In addition to balance evaluation all participants underwent fasting blood sugar test to diagnose diabetes, which allowed participants classification as diabetic (> 7 mmol/L) and non-diabetic (< 5.6 mmol/L). To assess the interaction among the usual aging variables that could interfere in balance assessments, all participants reported their previous 12-month history of falls. All assessments, physical examination and balance evaluation were performed by well-trained professionals. The falling occurrence was tracked monthly until the end of 1-year follow-up.

Group-exercising protocol

Of the participants who took part in the study, 77,3% (n = 58) older adults performed 50-min sessions of preventive supervised group-exercises, two to three-times per week for one year at the private clinic where the study was conducted. The exercise protocol included: (1) loaded "sumo" squats with halters for lower limbs strengthen, (2) Bilateral shoulder abduction/adduction and flexion/extension and elbow flexion/extension with halters for upper limbs strengthen; (3) For trunk, once-a-week, the training session was involved abdominal workout which was comprised by abdominal curl-up for rectus abdominis, bilateral crossed abdominal curl for obliquus muscles, and the drawing-in maneuver to activate the transversus abdominis. These training was followed by 30-min of step aerobics training Each exercise was comprised of 3 sets of 10 repetitions with 1-min rest between sets.

A 2-min rest interval was allowed between each exercise and the load was the same over the weeks. The load was applied following the perceived subjectively exertion (PSE). It translates, in a clinical way, how hard the participant feels like the body is working. It is based on the physical sensations experienced during physical activity including the increased heart rate, breathing rate, increased amount of sweating, and perceived muscle fatigue. In Addition, e Borg Scale was used to control the load on moderate to intense levels[27]. The participants were expected to work at moderate PSE.

Statistical analysis

Descriptive statistics were performed using absolute and relative frequency, as well as, means and standard deviations. Chi-square test of association ($\chi 2$) was conducted to verify the association between prospective falls and gender, history of falls, being diabetic and exercising in a prevention program. To evaluate the mean differences for age, weight, height, BMI and balance measures between fallers and non-fallers at 1-year follow-up, t-test of independent sample was applied. Effect sizes were expressed by means of Cramer's V and Cohen's d.

To provide a predictive model for prospective falls, several binary logistic stepwise hierarchical regressions were performed. Given the absence of a literature consensus on the best predictors of falls, simple binary regression models were previously conducted (i.e. the effect of each predictor on prospective falls was singly assessed). Therefore, the assumptions of absence of multicollinearity (Variance Inflation Factor less than 5) and outliers were assessed. The best fit model was judged based on the values of the Chi-square test, Hosmer and Lemershow test, Nagelkerk's R^2 and Odds Ratio (OR), considering its confidence intervals (OR [95% CI]). In addition, Log likelihood, Akaike Information Criteria and Bayesian Information Criteria values were inspected to assess model fit (i.e. the lower the better). All data analyses were run using the JAMOVI v. 1.2.19 software (The JAMOVI Project, 2020), with significance level set at 5%.

Results

Seventy-five older adults (71.8 ± 6.68 years) were evaluated at baseline. Most of them were women (n = 60, 80%), non-diabetic (n = 61, 81.3%) and performed the group-oriented exercise protocol (n = 58, 77.3%). There was no sample loss after 1-year follow-up. At baseline, 32% of participants (n = 24) reported previous history of falls. Of those, 41.7% (n = 10) reported having fallen over 1-year follow-up. Within those without previous history of falls (n = 51, 68%), only 13.7% (n = 7) reported having fallen over 1-year follow-up.

Descriptive test of association and comparisons between fallers and non-fallers after 1-years follow up are depicted in Table 1. History of falls, being diabetic and do not perform the group-oriented exercise were associated with prospective falls (Table 1).

Binary logistic stepwise hierarchical regression showed that the best predictors of prospective falls were having history of falling, being diabetic, and medio-lateral COP excursion during balance assessment ($\chi 2(3) = 19.240$; $p < 0.0001$, R^2 Negelkerk = 0.344). Hosmer and Lemershow test demonstrated that the predicted categories are equal to the expected categories ($\chi 2(7) = 11.261$; $p = 0.128$). Several models were run and the best fit model was retained. It showed lower values on Log likelihood, Akaike Information Criteria and Bayesian Information Criteria. The most adjusted binary logistic regression model can be seen in Table 2 (sensitivity = 0.948; specificity = 0.353; accuracy = 0.813). Non-significant predictors of prospective falls were not included in Table 2. All the assumptions of absence of outliers and multicollinearity were met (the higher VIF was 1.12). The perform the group-oriented exercise factor was not included in the predictive model but, instead, it was a protective factor for prospective falls (χ^2 (1) = 7.462; p = 0.006; V = 0.31; OR = 4.84 [95% CI = 1.47 to 15.9]).

Discussion

The present results only partially confirmed the proposed hypotheses. The binary logistic regression confirmed the predictive value of some classic risk factor for falls, as previous history of falls and presence of diabetes, however, disgregardes others classic factors described in literature related with balance, such as the path length, sway area and the sway velocity[28-30]. The single balance parameter ML excursion was included in the model due to its significance, but its predictive value was less important compared to other factors. The overall model showed excellent sensitivity and accuracy to detect those who were under risk of fall that really fall during the 1-year follow-up period, but the specificity was classed as poor. Also, the group-oriented exercise intervention was considered an important protective factor to prevent future falls.

History of previous falls is one of the most cited risk factors for falls[9,31]. The current findings emphasize the evidence that history of falls is an important and impactful factor to predict further falls in older adults. The history of fall assessment is direct and easily perform, so just ask about previous falls is an important first step[9]. However, a study assessed several medical questions (history of previous falls included) often used to classify the risk of fall in older adults using the post-test probability with the actual fall episode as the gold-standard[32]. The combined summary calculations showed small to moderate likelihood ratios and small change in the post-test probability of fall. The history of previous falls provided the largest increase in the post-test probability (~ 44%) though[32].

Despite its usefulness and fast response about the risk of falls, the history of falls does not subsidize the therapist with objective parameters to implement and track the intervention progression to effectively prevent a new fall event. Thus, other physical assessments are inevitable to ensure the potential impaired physical function to be

Table 1 - Descriptive, test of association and comparisons between fallers (n = 17) and non-fallers (n = 58) after 1-years follow up.

Variable	All subjects - Baseline	Prospective falls - 1 year follow-up		Statistic	*p*-value	Effect-size
	(*n* = 75)	Fallers (*n* = 17)	Non-fallers (*n* = 58)			
Gender[a]						
Female	60 (80.0%)	14 (23.3%)	46 (76.7%)	χ^2 (1) = 0.076[$]	0.54	*V* = 0.03
Male	15 (20.0%)	3 (20.0%)	12 (80.0%)			
History of falls[a]						
Yes	24 (32.0%)	10 (41.7%)	14 (58.3%)	χ^2 (1) = 7.269	0.007*	*V* = 0.31
No	51 (68.0%)	7 (13.7%)	44 (86.3%)			
Diabetes[a]						
Diabetic	14 (18.7%)	8 (57.1%)	6 (42.9%)	χ^2 (1) = 11.672	0.001**	*V* = 0.39
Non-diabetic	61 (81.3%)	9 (14.8%)	52 (85.2%)			
Prevention program[a]						
With group-exercise	58 (77.3%)	9 (15.5%)	49 (84.5%)	χ^2 (1) = 7.462	0.006*	*V* = 0.31
Without exercise	17 (22.7%)	8 (47.1%)	9 (52.9%)			
Age (years)[b]	71.80 (6.68)	72.71 (7.52)	71.53 (6.47)	*t* (73) = 0.633	0.52	*d* = 0.17
Weight (kg)[b]	66.17 (13.48)	63.48 (7.88)	66.96 (14.68)	*t* (50.44) = -1.280[#]	0.20	*d* = 0.30
Height (cm)[b]	157.36 (8.98)	154.65 (9.63)	158.16 (8.70)	*t* (73) = -1.427	0.16	*d* = 0.38
BMI (kg/m^2)[b]	28.73 (11.40)	26.39 (5.94)	29.42 (12.51)	*t* (57.46) = -1.389[#]	0.17	*d* = 0.31
Balance[b]						
Path length (cm)	83.12 (21.97)	89.87 (26.72)	81.14 (20.22)	*t* (73) = 1.451	0.15	*d* = 0.37
Mean velocity (cm/s)	4.18 (1.08)	4.49 (1.34)	4.09 (0.99)	*t* (73) = 1.37	0.18	*d* = 0.34
Mean distance (cm)	0.91 (0.20)	0.98 (0.20)	0.88 (0.20)	*t* (73) = 1.747	0.09	*d* = 0.50
Mean frequency (Hz)	0.74 (0.16)	0.74 (0.20)	0.75 (0.14)	*t* (73) = -0.067	0.95	*d* = 0.06
Root mean square ML(cm)	0.80 (0.39)	0.82 (0.26)	0.80 (0.42)	*t* (73) = 0.236	0.81	*d* = 0.06
Root mean square AP (cm)	1.15 (1.09)	1.73 (1.54)	0.98 (0.87)	*t* (19.052) = 1.928[#]	0.07	*d* = 0.60
95% CI ellipse area (cm^2)	9.61 (4.24)	10.90 (3.77)	9.23 (4.32)	*t* (73) = 1.431	0.16	*d* = 0.41
Excursion ML (cm)	3.17 (0.77)	3.39 (0.71)	3.11 (0.78)	*t* (73) = 1.36	0.18	*d* = 0.38
Excursion AP (cm)	3.82 (1.20)	4.19 (1.33)	3.72 (1.15)	*t* (73) = 1.442	0.15	*d* = 0.38

Note. χ^2 (1) = Chi-square with 1 degree of freedom; t (df) = t-test statistic with degrees of freedom (df); d = Effect size calculated using Cohen's d; V = Cramér's V effect size; ML = Medial-lateral; AP = Anteroposterior; BMI = Body mass index; 95% CI = 95% confidence interval. * p < 0.05; ** p < 0.01.

Table 2 - Binary logistic hierarchical regression (stepwise forward method) of predictors of prospective falls (*n* = 75).

Block	Variables		S.E.	Wald	df	p-value	OR [95% CI]
1	History of falls (Yes)	1.587	0.672	5.571	1	0.018*	4.890 [1.309-18.266]
2	Diabetes (diabetic)	2.173	0.737	8.693	1	0.003**	8.786 [2.072-37.254]
3	Excursion ML	-0.0823	0.402	4.202	1	0.04*	0.439 [0.200-0.965]
	Constant	-1.353	1.327	1.039	1	0.308	

S.E = standard error; df = degrees of freedom; OR = odds ratio; 95% CI = 95% confidence interval. * *p* < 0.05; ** *p* < 0.01.

addressed on training protocols[9,33]. Additionally, the patient's memory and cognitive impairments can be a bias of recurrent faller, non-faller or 1st time faller classification[13,34].

Evidence confirms the impaired ability to maintain the standing balance in older women with type 2 diabetes[35,36]. As balance is also a factor associated to risk of falls, those impairments indirectly link the rationale for falls episodes to people with diabetes. In the present results the single balance marker predicting falls associated to the presence of diabetes was the ML sway excursion. Declines in sensory function due to peripheral neuropathy and/or retinopathy, very prevalent in patients with diabetes, can lead to increased risk of falls in these people[37]. A study assessed the differences in dynamic postural motion, and the risk of fall in older men and women with type 2 diabetes[36]. In this study, thirty-seven older individuals were allocated in 4 groups (control-non fallers, control fallers, diabetic-non fallers and diabetic fallers), and performed double leg stance in four different conditions (combination of eyes open/closed with firm/foam surface). The sway amplitude was decreased with higher standard deviation and higher sway velocity in the diabetic fallers group during more challenging conditions. They hypothesized the decreased amplitude occurs simultaneously to the increased frequency of postural sway, and that such changes were due to an increased body stiffness. Another study showed that stepping threshold was affected by diabetes in older adults[38]. Delayed stepping may impair the ability to recover the dynamic or static reactive balance after a postural perturbation, such as slipping or stumbling and lead to falls. A study reinforced the mandatory glycemic control on those diabetic older adults due to increased risk of an injurious fall[38]. The findings showed that older adults with diabetes, especially those using insulin, are at greater risk of injurious falls requiring hospitalization than those without diabetes. The present findings showed a huge OR for those diabetic older adults, also confirming the urgent care for those with uncontrolled blood glucose.

The ML excursion represents the difference between the maximal and the minimal body sway displacement in ML direction. The ML excursion in single stance was associated with the ability to use the hip's abductors-adductors and the ankle's pronators-supinators muscles to distribute body weight between lower limbs, while AP sway is associated with variations in ankle flexor muscles activity[39,40]. A study showed that older adults with retrospective falls showed decreased AP and ML sway, and ML excursion was significantly smaller compared to those without previous falls during dynamic postural control tasks[11]. However, evidence seems conflicting concerning the best posturographic sway parameters to predict falls in older adults. Nevertheless, a review with meta-analysis comprising 7,176 older adults identified from a sensitivity analysis the consensual characteristics for early risk of falling diagnosis[41]. The sway area per unit time, along with the AP mean velocity, and radial mean velocity were the best traditional features. However, the references' screening included both prospective and retrospective studies with several types of protocols to assess body sway during stance. The authors highlighted that complex sway analysis are not sufficiently explored in the literature.

Due to exercising, the current findings might also be altered as exercises do change postural strategy by increasing muscle strength, reactiveness, and stiffness[2,18,42-44]. In this sense, the prediction modeling must be combined to other assessments and principles, such as the protective effect analysis and type of protocol addressed during the intervention period. In fact, those above-mentioned results reaffirm the exercise role in preventing injurious outcomes from an episode of falling. As expected, the fall prediction was changed due to improvements of the target parameters affected by the exercise protocol: the muscles activity and the balance strategies. Thus, the theory is that other measurements were more relevant to predict prospective falls other than balance parameters.

The most important aim of a screening is to determine how sensitive a diagnostic test is in predicting an outcome, when both the test and variable for clinical diagnosis are presented as dichotomous data[11,45]. From those results, the prediction model performance and its efficiency are often classified. Despite the low values for the specificity testing, the major objective was to detect those under risk of future falls, which was achieved with approximately 94% of prospective fallers correctly classified. The present responsiveness analysis returned good levels of accuracy and excellent sensitivity to predict future falling events in older adults.

The novelty of the present study is the prospective follow-up to address the baseline factor predicting the actual twelve-months fall episode and the practice of a standardized group-oriented exercise intervention. As previously mentioned, the results showed the combination of diabetes, history of previous falls and the specific ML excursion as predictors for prospective falls. These results highlight the need for balance assessments that are focused on these parameters actually able to be enhanced by exercising and preventive measures. Also, the priority for diabetes controlling would significantly affect the falling outcomes in older people.

Some limitations of the present study must be addressed. The non-exercising group was asked not to perform any type of conditioning during the protocol. However, it is impossible to impose and monitor such condition. The sample was majorly constituted by women. Thus, the results may vary with different proportions of male and female. The prediction model might be affected by the exercise routine, and the predictors are valid if considered in combination to a protective analysis. The specificity was poor to detect those without risk of falling. Other physical components were not assessed and may alter the primary outcome (e.g. handgrip and lower limb strength, hearing impairments). The exercise routine was designed for groups. The supervision was close to each participant, but detailed execution is often missed. There is always a probability of distinct effects using one-to-one approach for exercise prescription, and that should be considered for further studies.

Conclusion

The proposed model was able to accurately predict those older adults under the risk of prospective falls. Group-oriented exercise intervention was effective to protect older people from prospective falls events. The prediction model might be altered by the exercise routine, and the assessment should include both evaluations to understand the further needs of older people, responsive or not to the applied protocol. The findings strongly indicate the importance of group exercising to control the risk of falls in older adults. Additionally, the diabetes controlling is crucial to avoid prospective falling events.

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