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Article

Fall risk prediction model for older men and women based on ambulatory physical activity level – A cross-sectional population-based study from the Oporto Region

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Abstract: Introduction. Falls among the elderly are an important community health problem due to its high incidence, functional and social repercussion. Dissimilar results arose in recent studies concerning fall risk and physical activity levels. This study measures the association between physical activity (PA) levels, and fall risk (FR), investigates which levels of PA are influential in FR and presents a fall risk prediction models for the elderly. Material and Methods. One hundred and seventy elderly adults (72.34 ± 6.70 years old, 124 female), completed Performance-Orientated-Mobility-Assessment; PA was assessed by accelerometry. Pearson's correlation verified the association between FR, Age, and PA. Multiple linear regression (MLR) was used to investigate the influence of variables on FR. Results. PA, age are predictors of FR, with PA (moderate, negative) age (moderate, positive). MLR analysis showed FR variability explained by PA (42.0%) and by age (37.0%), and by gender, female FR explained by light PA (47.0%), while in male, FR explained by sedentary behaviour (44.1%) and age (22.7%) independently. Conclusion. Individuals with higher physical activity have lower fall risk. Older are prone to fall. Older women with light physical activity are less likely to fall. Older men with more sedentary behaviour are prone to fall.

Keywords: active aging, accelerometer, balance, motor activity levels, sedentary behaviour.

1. Introduction

Increased age-related falling incidence is an important public health concern that affects 30% of individuals beyond 65 years of age [1, 2] and up to 50% of individuals older than 75 years [3–6].

The high incidence, long-term effects, loss of autonomy and costs for support, recovery and rehabilitation of falls will increasingly impact our health care system as time goes on [7]. In this sense, the diagnosis of clinical, behaviour and functional parameters associated with falls in the elderly has become a major challenge for the scientific community [8].

Most falls are caused by the interaction of multiple intrinsic and extrinsic risk factors [9–11], presenting lifestyle, namely physical activity (PA), an important role in the occurrence of falls [12]. However, while the majority of studies showed that PA is associated with decreased risk of falling and fractures [13–17], others state that there is no relationship or even that PA is associated with in increased risk of falling [18]. This inconsistency is probably justified by different methodologies used in the studies, especially in the determination of PA: subjective – self-reported methods vs objective ones – accelerometers [19–22].

Furthermore, the relationship between fall risk (FR) and different levels of PA and, particularly, with sedentary behaviour (SB), as a behavioural risk factor for many non-communicable diseases [23], has not been so extensively researched. The majority of studies on SB have investigated its effects on cardiovascular outcomes and physical function; however, literature is scarce regarding the impact of SB on the occurrence of falls. So, SB as well as different levels of PA, defined as any bodily movement that increases energy expenditure above a basal level, may differently contribute to FR [17].

Thus, the main aim of the study was to examine which PA levels and/or SB better predict fall risk (FR). Besides, taking into account that prediction models for FR have been developed mainly for residents of nursing homes, with scarcer studies for the general community-dwelling elderly adults, we sought to develop a predictive model based on SB and PA levels that could be applied to those aged 65 years and over living in community.

2. Materials and Methods

2.1. Participants

Two hundred and six individuals, aged 65 years and older, drawn from the Oporto area, Portugal, were invited to participate in this cross-sectional study. The exclusion criteria were: those unable to walk without a cane, or those with known medical, cognitive conditions and muscular-skeletal problems that would limit their ability to safely perform evaluations. Following the screening, 36 candidates did not perform all tests to the required selection criteria standards, resulting in a final suitable sample size of 170 participants (mean age = 72.3 ± 6.7 years; 124 women and 46 men).

Subjects were informed about the study aims and procedures and then signed written informed consent before being enrolled in the study, respecting Ethical Guidelines [24] and the World Medical Association Declaration of Helsinki [25, 26]. The study was approved by the proper Ethics Committee.

2.2. Measurements

2.2.1. Physical Activity

Habitual ambulatory physical activity (PA) was assessed using uniaxial accelerometry (GT1M, Actigraph, Florida, USA). Participants were instructed to wear the accelerometer on an adjustable nylon belt over the right hip, for seven consecutive days, apart from sleeping and during water-based activities, and also to record activities in a written diary [27].

Wear time validation was used, whereby continuous periods of 60+ consecutive minutes of continuous zero counts, with a tolerance of up to two minutes of activity within the range of 0–100 counts.min-1 (CPM) were defined as "no-wear" and excluded from the analysis. Data were considered valid if there was a minimum of 10 hours of wear time per day, on a minimum of four days [28, 29]. Data from all participants meet these validity criteria and none were excluded.

ActiGraph data was processed using Actilife™ software (v.6.11.3 ActiGraph, Pensacola, FL.) that converts acceleration data into counts that are summed over a user-specified interval of time called an "epoch". For the present study, the epoch was set to a 10-second interval, which allows the highest resolution. The outcome variable was reported in minutes, that is, the number of the vertical axis counts.min-1(CPM) and were generated based on the magnitude, intensity and frequency of bodily movement. Thus, the higher number of counts measured, the more active a person is. CPM is often used as an outcome variable due to its robustness, as it is not influenced by any external criteria (i.e., intensity threshold) other than wear time validation [28, 30].

Inactivity or sedentary behaviour (SB) was classified as activity below an arbitrary level of 100 CPM, and the cut-off points for light PA (LPA; 500–1,999 CPM), moderate PA (MPA; >2,000 CPM) and vigorous PA (VPA; >3,000 CPM) were all set in consistence with Sardinha et al. (2008) [27].

2.2.2. Fall risk

Performance Orientated Mobility Assessment (POMA) developed by Tinetti [31] was used. This assessment tool shows proven sensitivity and specificity for fall prediction [32] resulting in a widespread use of POMA in both research and clinical settings [33]. POMA consists of 2 parts for assessment of balance and gait and is frequently used to evaluate elderly populations. The score ranges from 0 to 28, and a score of 0–19 corresponds to high fall risk, while scores between 19–24 reveal the presence of a problem, classified as moderated fall risk, whereas a score of 24–28 correspond to low fall risk [34–36].

The higher the POMA score, the lower fall risk. Hence, when the POMA score tends to zero, meaning an increase in fall risk, this may be misleading. Thus, in the present study POMA was inverted into a new variable, called fall risk (FR) [37–39]. FR was created based on POMA score results by applying the formula (FR = 29 – POMA), and the new score ranges were categorized as: low FR (1–5), moderate FR (5–10), and high FR (10–28).

2.3. Statistical Procedures

SPSS 25 for Mac (SPSS Inc., Chicago, IL, USA) was used for statistical analysis. All continuous variables were expressed as mean ± standard deviation and were initially evaluated for normality using the Kolmogorov–Smirnov test.

Differences between men and women for age, POMA, FR, PA levels and clinical conditions were compared via independent sample t-test. Afterwards, the Pearson correlation coefficients test was used to assess the correlation between PA, FR and age, and the inferential stepwise Multiple Linear Regression test was used to investigate multivariate relationships among predictors of FR. The assumptions of the models, namely, normal distribution, homogeneity and independence of errors were analysed and used the criteria: probability-of-F-to-enter $<= 0.05$, probability-of-F-to-remove $>= 0.10$. G*Power was used to obtain the effect size F2 and power of the tests. The level of significance was set at $p < 0.05$.

3. Results

Table 1 shows scores for age, POMA, FR, PA levels and clinical conditions. Significant differences were evident between males and females regarding PA levels: men exhibited greater sedentary behaviour ($p = 0.027$) and smaller light PA ($p = 0.012$). Slight differences (not significant) were found between genders in POMA, static, and dynamic balance, with men presenting better results; however, both genders had a normal score with M = 26.26 (> 24). Thereby, regarding FR, both genders presented low FR (< 5). No other differences were observed in all the other components/aspects of physical activity and clinical diseases between genders.

Table 1. Variable values of age, POMA, FR, PA levels, and clinical conditions by gender and independent samples t-test between genders *p* – values results.

Variable	Mean (SD)			*p*
	Total	Female	Male	
Gender N/(%)	170 (100)	124 (72.9)	46 (27.1)	< 0.000*
Age (years) mean SD)	72.34 (6.70)	71.97 (6.57)	73.35 (7.01)	0.281
POMA Score	26.26 (2.99)	26.10 (3.30)	26.67 (1.92)	0.318
Static balance	14.80 (1.85)	14.71 (2.01)	15.05 (1.31)	0.324
Dynamic balance	11.45 (1.41)	11.39 (1.57)	11.62 (.84)	0.391
Fall Risk	2.74 (2.99)	2.90 (3.30)	2.33 (1.92)	0.318
PA (CPM)	4.63 (2.17)	4.70 (2.28)	4.42 (1.80)	0.529
SB (mean/hour)	449.87 (83.63)	440.61 (86.51)	477.10 (68.64)	0.027*
LPA (mean/hour)	274.29 (88.65)	285.38 (92.82)	241.68 (65.99)	0.012*
MPA (mean/hour)	20.42 (19.10)	19.32 (18.72)	23.64 (20.12)	0.256
VPA (mean/hour)	0.05 (0.19)	0.03 (0.18)	0.08 (0.23)	0.152
MVPA (mean/hour)	20.46 (19.16)	19.35 (18.77)	23.73 (20.21)	0.251
Cardiovascular system N/(%)	78 (45.88)	60 (48.38)	18 (39.13)	0.132
Musculoskeletal system	26 (15.29)	17 (13.71)	9 (19.57)	0.233
Respiratory system	19 (11.17)	13 (10.48)	6 (13.04)	0.269
Digestive system	5 (2.94)	3 (2.41)	2 (4.35)	0.310
Signs, symptoms and conditions ill-defined	21 (12.35)	16 (12.90)	5 (10.87)	0.421
Other diseases	3 (1.76)	2 (1.61)	1 (2.17)	0.654

Key: POMA – Performance Orientated Mobility Assessment; PA – physical activity; CPM – counts per minute; SB – sedentary behaviour; LPA – light physical activity; MPA – moderate physical activity; VPA – vigorous physical activity; MVPA – moderate to vigorous physical activity; SD – standard deviation; *p* – *p* value; * – denotes statistical significance, $p < 0.05$.

Associations among age, physical activity levels and fall risk are shown in Table 2. Table 2 shows that FR significantly and positively (moderate) [40] correlated with age (r = 0.385, $p < 0.001$) and negatively with PA (r = -0.320, $p < 0.001$). All other correlations of FR were non-significant and negative with SB, LPA, MPA, VPA and MVPA.

Table 2. Correlation analysis (Pearson's test) of participants' age, PA, and FR.

Variables	FR			PA		
	r	*p*	Class	*r*	*p*	Class
Age	0.385**	< 0.001	M	-0.471**	< 0.001	M
SB	-0.035	0.700	S	-0.305**	< 0.001	M
LPA	-0.099	0.278	VS	0.568**	< 0.001	L
MPA	-0.153	0.093	S	0.809**	< 0.001	L
VPA	-0.082	0.370	VS	0.239**	0.005	S
MVPA	-0.153	0.092	S	0.809**	< 0.001	VL
PA	-0.320**	< 0.001	M	----	----	----

Key: FR – fall risk; PA – physical activity; SB – Sedentary Behaviour; LPA – light physical activity; MPA – moderate physical activity; VPA – vigorous physical activity; MVPA – moderate to vigorous physical activity; SD – standard deviation; *p* – *p* value; * – denotes statistical significance, $p < 0.05$. Correlation is significant at the 0.01 level (2-tailed) **; Correlation is significant at the 0.05 level (2-tailed) *; Class – *r* classification according to Hopkins (1997) [40]: VL – very large; L – large; M – moderate; S – small; VS – very small.

Moreover, significant and negative correlations (moderate) [40] between PA and SB (r = -0.305, p < 0.001) were seen. Furthermore, PA correlated significantly, negatively and moderately with age (r = -0.471, p < 0.001). Finally, no other non-significant correlations were observed between variables.

An inferential stepwise *Multiple Linear Regression (MLR)* was undertaken to estimate the contribution of (i) age, (ii) PA levels, and gender to explain the variability of FR (Table 3). The MLR analysis found that PA significantly predicted FR (β = -0.869; t(81) = -7.725; p < 0.001), as did age (β = -0.223; t(81) = -2.079; p < .041), explaining PA (45.0%) and age (43.0%) independently, and even more when associated, predicting both, 52.1% of the variance of FR (R^2 = 0.521, F(6,115) = 0.978; p < 0.001). Thus, according to Table 3, adding age to the analysis increases the explanation of FR variability by 7.1% (52.1 minus 45.0). This study total sample adjusted model is then $\widehat{\boldsymbol{FR}}_{\text{Total}}$ = 8.289 – 0.134 PA + 0.114 age, meaning that the older participants have a greater fall risk, but the more active ones are less likely to fall.

Table 3. Multiple linear regression models predicting FR in the total, female and male samples.

Model		R^2	R_a^2	SEE	Predictive formula
1_{Total}	PA	0.450	0.420	3.082	
2_{Total}	Age	0.430	0.370	2.942	
FR_{Total}	Predictive variables	0.521	0.473	3.005	$\widehat{\boldsymbol{FR}}_{\text{total}}$ = 8.289 – 0.134 PA + 0.114 age*
1_{Female}	LPA	0.483	0.470	2.756	
FR_{Female}	Predictive variable	0.483	0.470	2.756	$\widehat{\boldsymbol{FR}}_{\text{Female}}$ = 9.882 – 2.113 LPA*
1_{Total}	SB	0.472	0.441	2.232	
2_{Total}	Age	0.318	0.227	2.735	
FR_{Total}	Predictive variables	0.469	0.458	2.785	$\widehat{\boldsymbol{FR}}_{\text{Male}}$ = 8.229 + 2.324 SB +0.665 age*

Key: FR – fall risk; PA – physical activity; * – denotes statistical significance, p < 0.05; Variables entered: Age; SB; LPA; MPA; VPA; MVPA; PA. Dependent variable: FR. Predictive variables: Model 1_{Total} – PA, Model 2_{Total} – Age. Model FR_{Total} – PA +Age; Model 1_{Female} – LPA, Model FR_{Female} – LPA; Model 1_{Male} – SB, Model 2_{Male} – Age, Model FR_{Male} – SB + Age; R^2 – determination coefficient; R_a^2 – adjusted determination coefficient; SEE: standard error of estimate.

Gender was not a significant predictor (data not shown). Yet, mainly due to PA levels dissimilarities between genders (Table 1), and proceeding the statistical analysis of data, a *MLR* of the sample with gender stratification was carried out, reaching the models $\widehat{FR}_{\text{Female}}$ and $\widehat{FR}_{\text{Male}}$ also presented in Table 3.

MLR of the female sample (Table 3) found that light PA significantly predicted FR (β = 0.030; t(84) = 11.535 p = 0.020) and explained 47.0% of the FR variability (R^2 = 0.470, F(6,84) = 0.582; p = 0.020). The female adjusted model is then $\widehat{FR}_{\text{Female}}$ = 9.882 – 2.113 LPA, meaning that old women with more light physical activity are less likely to fall.

MLR of the male sample (Table 3) found that the FR variability was mainly explained by sedentary behaviour (44.1%) and significantly predicted *FR* (β = -0.046; t(24) = -4.144; p < .001), and also independently, with minor expression, by age (22.7%) (β = -0.298; t(24) = -2.653; p = 0.041). With both predictors associated, it explained 45.8% of the FR variability R^2 = 0.458, F(6,24) = 4.710; p = 0.003). The male adjusted model is then $\widehat{FR}_{\text{Male}}$ = 8.229 + 2.324 SB + 0.665 age, meaning that old men with more sedentary behaviour are more prone to fall risk; furthermore, the older they are, the higher fall risk appears. Likewise, the older and/or more sedentary men are, the more likely they are to fall.

In the total sample model using G*Power, with age and PA, the effect size (f^2 = 0.558701) was found to exceed convention for a large effect (f^2 = 0.83223) [41], and it observed statistical power (π = 1.000). In the female sample model using G*Power with LPA, the effect size (f^2 = 0.7533136) was found to exceed convention for a large effect (f^2 = 0.50) [41], and it observed statistical power (π = 1.000). Furthermore, in the male sample model, using G*Power with SB and age, the effect size (f^2= 0.7581294) was found to exceed convention for a large effect (f^2 = 0.50) [41], and it observed statistical power (π = 0.9434250). All three were suitable for detecting a large-sized effect when employing 0.05 criterion of statistical significance.

4. Discussion

The major finding of this study is that PA (negatively) and age (positively) are major FR predictors in older adults. This finding highlights the importance of considering these physical activity components in FR assessment models.

The *MLR* showed that FR variability was mainly explained by PA (42.0%) and also, with minor expression, by age (37.0%) independently, and even more when associated (47.3%). Our final adjusted model ($\widehat{FR}_{\text{Total}}$ = 8.289 – 0.134 PA + 0.114 Age) suggests that more active older adults will have a lower fall risk, and the oldest ones will be prone to a greater fall risk. This model is highly significant ($p < 0.05$) and accounts for a large proportion (≈ 52%) of the FR variability.

It is important to highlight that our model accuracy was achieved by encoding not only demographic variables but also different PA levels and SB. In this way, gender stratification showed that light PA in women and sedentary behaviour in men are significant FR predictors. By identifying those community-dwelling aged 65 years and older who are more likely to fall, the predictive model can better direct preventative efforts. In this way, and according to literature [42, 43], sedentary behaviour should be avoided and, in opposition, light-to-moderate PA should be encouraged [44].

Regarding PA levels, differences were evident between males and females, with men presenting with greater SB (p = 0.027) and smaller LPA (p = 0.012). These differences might help understand the different models obtained by MLR.

The observed correlations between total physical activity PA and the health-enhancing physical activity (moderate and vigorous PA) are in line with different studies that reported that older adults with higher PA performed better in POMA evaluation [42]. The relevance of active lifestyles for a lower FR is thus highlighted. The model's predictions are valuable because they identify the older men who are sedentary and the older women that present light activity who are most at risk.

This is of importance since falls and fall-related injuries are common, particularly in those aged over 65, with around one-third of older people living in the community falling at least once a year [45, 46]. So, diagnosis behaviour parameters associated with falls in order to better design fall prevention interventions, namely by changing lifestyles and PA behaviours, are of importance. Multiple component interventions, usually including PA (or exercise) habits, may reduce the rate of falls and risk of falling in community-dwelling older adults [47–49], just as reported here.

Balance is also subject to the biological aging process [50], by a multiplicity of factors, such as muscular strength of the legs and torso that usually deteriorate with age, thus making age also one of the predictors of balance disorders, and consequently of fall risk [51–53].

On the other hand, physical activity and physical exercise may act as a potential non-pharmacological intervention in reducing fall risk due to its multiple effects on strength, balance, and fear of falling [54–58].

By contrast, the observed negative correlation between average total PA and sedentary behaviour might raise some questions. This result might be due to the argument of lack of opportunity, since participants with high SB during daytime window will not perform as others, preventing them from reaching the activity levels of others with a more active and healthier lifestyle.

Thus, it seems that the presence of an active lifestyle, where mobility is high, promotes better performance in dynamic balance by reducing the FR. It is important to improve the practice of PA as a way to delay this ageing [50, 59], but no way to halt it indefinitely [60].

The statistical analysis got robust results and achieved large effect size values. To highlight the relevant and original findings of the present study: lower FR correlated significantly, highly, and positively with higher PA and negatively with older age, and higher PA correlated significantly, highly, and positively with bigger LPA, MPA, VPA, and MVPA, and negatively with older age.

This study final adjusted model is then $\widehat{FR}$ = 8.289 – 0.134 PA + 0.114 Age, meaning that more active elderly persons will have a lower fall risk, and older elderly persons will be prone to a greater fall risk. Regarding the relative weight of PA levels as a predictor variable of FR, the *MLR* showed that FR variability was mainly explained by PA (42.0%) and also, with minor expression, by age (37.0%) independently, and even more when associated (47.3%). This model is highly significant ($p < 0.05$) and accounts for a large proportion (≈ 52%) of FR variability.

No other study like the present one was found that showed an association model with the variables that resulted in the *MLR* model reported here. Cut-off points based on ambulatory activities have only been criticized, and different cut-off points, including both ambulatory and non-ambulatory activities, have been suggested to categorize light, moderate, vigorous, and very vigorous levels of physical activity [61, 62]. In the present study, the authors tried to use the best practices developed so far [63] and in the current national practice [64]. With this in mind, the use of another set of cut-off points might produce distinct models.

4.1. Strengths

The strengths of this study include the use of objective and reliable instruments by ACM. This methodology provides objective measures of physical activity behaviours that are free of the random and systematic errors associated with self-report. As such, they are believed to provide better assessments for many activities, particularly activities that have proved difficult to measure by self-report (e.g., walking) [42]. Also, to avoid seasonality effects, data were collected for over 14 months. The sample size did not limit the statistical power of the analysis and may have contributed to correlates of PA and age, in both genders.

4.2. Limitations

Nonetheless, this study is not without limitations. First, the sample size was relatively small, and although it did not limit the statistical power and comprised volunteer subjects, this makes generalization of the results difficult. The division of the sample by gender was made, which could threaten the strength, or would jeopardize the robust statistical analysis. Secondly, cross-sectional design does not permit causality conclusions. Future large-scale trials are warranted to investigate which factors are more effective on fall parameters using sensitive measures. Third, data on other potential confounders, such as visual impairment, foot problems, among others, were not assessed. Fourth, the history of falls as a factor of exclusion was chosen, based on the relative increase of the risk to which the participants were exposed during data collection.

Even considering these limitations of the study, the data information of the present study may be important for general practitioners and geriatricians who are responsible for observing, studying, evaluating and early identifying older people with potential fall and balance disorders, in order to suggest active interventions with non-formal or formal physical activities that can mitigate or delay fall risk.

5. Conclusions

This cross-sectional study showed that lower fall risk is achieved in younger and more active participants. Among all of the predictors of fall risk, older men with more sedentary behaviour have an increased fall risk, while more light physical activity in women may decrease fall risk.

This knowledge is of utmost importance and reinforces the strategy for improving physical activity exercise programs for population in general, and specifically for the elderly, promoting active aging with physical activity, in the form of walking and running activities. Working towards fall risk hazards diminution and restraints could be fundamental to promote better autonomy in community-dwelling elderly persons and better understanding how health care providers and elderly caring personnel could impact the falls burdens in social economy.

5.1. Practical implication

These findings will be useful for clinicians, for caregivers, for health managers in the primary health care service that would use physical activity, sedentary behaviour and light PA scores to categorize high risk fallers among the elderly.

Since these predictors or risk factors are potentially modifiable, rehabilitation programs could be designed to reduce the FR in the elderly that would include physical exercise to improve mobility, strength and dynamic balance as well as to reduce sedentary lifestyles.

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