ORIGINAL RESEARCH

Disentangling the relationship between falls, fear of falling, physical function and walking by applying a socioecological framework to the International Mobility in Aging Study

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Abstract

Introduction:
The relationships between falls, fear of falling, poor mobility, and PA avoidance occur in a cyclic, multi-directional fashion. Aim: This study investigates the concomitant associations of fall history, fear of falling, and physical performance (SPPB) on physical activity using a cross-national sample of community-dwelling older adults from middle and high-income countries.

Methods:
Linear mixed-effects models looking at the influence of individual and environmental factors were used and participants were nested within each study site.

Results:
Estimated walking minutes was 52% lower for those with low SPPB compared to high SPPB, 20% lower for those with medium level fear of falling compared to low levels, and 50% lower for those with high level fear of falling compared to low levels.

Conclusion:
An individual's fear of falling and physical performance may be important to consider when making PA recommendations to older adults regardless of sex, age, and environment.

Keywords: *Fall, fear of falls, gerontology, global health, physical function, walking.*

Introduction

Falls are a major public health concern for older adults globally. It is estimated that 30% of community-dwelling older adults (>65 years) will fall at least once per year [1]. Across the globe, 80% of fatal falls occur in low- or middle-income countries [2]. Non-fatal falls often lead to serious medical injuries that result in loss of disability-adjusted life years, which can be costly for the individual and his/her community [3]. Overall, it is estimated that significant injuries occur in 4-15% of falls and 23-40% of injury-related deaths in older adults are due to falls [4].

Fear of falling (FoF) is observed in 50%-60% of community-dwelling individuals who have fallen [2] and is identified as a significant health concern because of its close association with falls and other mobility-related measures. Correlates to FoF, such as low mobility [5], frailty, and low physical activity (PA) behavior [6, 7] overlap with fall risk factors. Thus, falls, fear of falling, poor mobility, and PA avoidance occur in a cyclic, multi-directional fashion [8] and should be considered together. There is limited research that considers falls, FoF, physical function, and PA together and at the same time accounts for individuals and environmental influences.

The socioecological model has been successfully used as a framework to understand mobility limitations in older adults in the past [9, 10] and may prove useful for conceptualizing the complex relationship between falls and PA. This framework provides a broader perspective on the determinants of PA behavior by considering the context of a health behavior within different social and physical environments, thus bridging the gap between individual and environmental constructs [11]. In this article, we propose to use the socioecological model as a framework to investigate the concomitant associations of fall history, FoF, and physical performance on PA using a cross-national sample of community-dwelling older adults from middle and high-income countries. This study examined models that included individual risk factors commonly associated with falls, such as sex, age, fall history, and FoF, and perceived environmental risk factors such as, uneven sidewalks, community safety, and community barriers.

Results from this study help better identify how individual and environmental-level fall risks affect an older adult's PA levels in diverse populations in order to improve falls related interventions.

Methods

Data Source

Data were collected as part of the International Mobility in Aging Study (IMIAS) at the following study sites: Kingston (N=398) and St. Hyacinthe (N=401), Canada; Tirana, Albania (N=394); Natal, Brazil (N=407); and Manizales, Colombia (N=402). Each site sampled near equal proportions of men and women, with the total sample containing 955 men and 1047 women. These diverse sites were chosen because the varying demographic factors maximize the spectrum of exposures that participants face across the life-course, allowing for exploration of distributional tails that would have been impossible with a single site [12]. Baseline data were obtained in 2012, with follow-up collections in 2014 and 2016. Only baseline data for the five sites were used for this study.

Participants comprised of community-dwelling older adults aged 65 to 74 at baseline. University ethics committees did not allow researchers to recruit or contact potential participants directly in Kingston and St. Hyacinthe. Thus, participants were recruited through their physicians in these sites. In Tirana, Natal, and Manizales, participants were randomly sampled and recruited from health center registries. Potential participants were then approached directly by interviewers to participate in the study [1]. All interviewers were trained according to a standardized protocol. Response rates were 90% in Tirana and nearly 100% in Manizales and Natal. While 30% of invited participants in Kingston and St. Hyacinthe contacted the field coordinator, 95% agreed to participate in this study. Individuals who had four or more errors on the Leganes Cognitive Test orientation scale [13] were excluded from the study, as low scores indicated an inability to complete study procedures. Gomez et al compiled a cohort profile to describe recruitment and retention details [14].

Principal Exposures

Principal exposures for this analysis were personal level factors: fall history in the last year, physical performance, and FoF. Fall history (yes/no) was assessed by asking participants whether or not they had fallen within the past 12 months. Physical performance was evaluated with the extensively validated Short Performance Physical Battery test (SPPB), which includes tests of balance, gait speed, and chair stand. Each component has a maximum score of four. Total possible SPPB score 0-12 and the battery is described in detail elsewhere [15]. To simplify results' interpretation, we recoded the total SPPB score into a binary variable of high versus low physical function. SPPB scores of less than eight indicate low or limited physical performance, and SPPB scores of eight of more indicate higher physical performance [16]. FoF was assessed with the Falls Efficacy Scale International (FES-I) questionnaire (Yardley et al. 2005). FES-I quantifies the fall concerns of older persons related to 16 activities that occur inside and outside of the home. The level of falling concern was measured on a four-point Likert scale (1 = not at all concerned to 4 = very concerned). Total FES-I scores range between 16 and 64, with higher scores indicating greater concern. For this study, FES-I scores were categorized into three groups: no/low [15-18], moderate [19-26], and high (>27) concern about a fall [17].

Outcome

For PA, average minutes walking daily over a week was a continuous measure collected with a validated computer animated assessment tool for older adults, the Mobility Assessment Tool for Walking (MAT-W) [18].

Perceived environmental-level covariates

Since the perceived environment has a stronger association with PA behavior than objective environment [19], two perceived physical environment factors, uneven sidewalks and a community barrier scale (CBS), and a perceived social environment measure, Perception of Safety Scale (PoSS) were included in the analysis. Missing values for both CBS and PoSS variables were imputed. The presence of uneven sidewalks in the participants' neighborhood is a self-reported variable that was assessed by asking "Does your neighborhood have uneven sidewalks?" Responses were measured using a Likert scale: 1- A Lot, 2- Some, 3-Not at all. For this study, responses were categorized as yes or no. "Yes" included the responses "A lot" or "Some." "No" reflected the response "Not at all." Participants that indicated "I don't know" (n=80, 4%) were excluded from this study and labelled as missing.

CBS was developed using explanatory and confirmatory factor analyses on 8 items related to local community from the Home And Community Environment (HACE) scale [20]. Three items--parks/walking areas that are easy to access and use; safe parks/walking areas, and places to sit and rest at bus stops; parks, or other places where people walk--loaded into a single factor. The absence of an item (e.g. park/walking area) was considered a community barrier [21]. The sum of barriers ranged from 3 to 9. The higher the score, the more perceived barriers. Since preliminary analysis showed a non-linear relationship between CBS and walking, CBS scores were categorized into tertiles of high, middle, and low scores.

PoSS was developed using explanatory and confirmatory factor analyses on 10 items on perceived safety developed by Sampson and Raudenbush [22, 23]. Our measure of PoSS, after the factor analyses, included 8 items with possible range of 8 to 24. The higher the score, the safer the individual perceived his/her community. Since preliminary analysis showed a non-linear relationship between PoSS and walking, PoSS scores were categorized into tertiles of high, middle, and low scores.

Individual-level covariates

Education, age, sex, and site location were chosen as covariates based on the socioecological models used to examine older adult mobility determinants [10]. Sex, age, and education are personal-level attributes. Total years of education were split categorically into tertiles of high, medium, and low education by site to obtain a variable called "relative education". Thus, a participant can have high educational attainment relative to his/her community, but medium or low attainment compared to another site in IMIAS. Sex is an interviewer reported categorical variable (male/female). Age is a self-reported continuous variable re-coded into a binary categorical variable (64-69/70-75).

Analysis

STATA/SE (version 14.0; StataCorp LP, College Station, TX USA) was used to conduct the analyses. One-way ANOVA analyses were performed to test differences in average minutes walking per day for all variables. Multivariate linear mixed-effects models were used to examine the strength and direction of the relationship between covariates and outcome measures aggregated by study site (Kingston and St. Hyacinthe, Canada; Tirana, Albania; Manizales, Colombia; and Natal, Brazil). Figure 1 depicts the conceptual model underpinning our analyses. The linear mixed-effects models were used because of the hierarchical structure of the data with IMIAS participants nested within study sites. Four models were generated to test whether individual-level and perceived environmental-level exposures affect the relationship between walking and falls, fear of falling, and SPPB. For these models, we allowed the intercepts to vary randomly and estimated the site-level intra-class correlations (ICC). The estimated ICC provided the proportion of variation explained by between-site variations, i.e., within-site similarity adjusting for covariates. Initial analysis showed that the residuals of the outcome variable, minutes of walking, were positively skewed, therefore it was log transformed to meet the model assumptions. Regression coefficients were exponentiated (e.g. back-transformed) to provide meaningful interpretation in the tables. The exponentiated values are the changes in the ratio of the expected geometric means of the original outcome variable. Variance inflation factors were calculated for the multivariate models to inspect for collinearity and showed that there was little collinearity between variables due to the low variance inflation factor (VIF).

Figure 1: Conceptual Framework Depicting the Inter-relatedness of Physical Activity with Fear of Falling, Physical Performance, and Fall History

Ethics

All methods were carried out in accordance to the guidelines and regulations set by the ethical committees per prospective site. Ethical approval for this project was obtained from the ethics review committees of the research centers of the University of Montreal Hospitals (CR-CHUM), Queen's University (Kingston), the Albanian Institute of Public Health, the Federal University of Rio Grande do Norte (Brazil) and the University of Caldas (Colombia). Informed consent was obtained from participants prior to the start of the study. No participants under 18 years of age were included in this study.

Results

Table 1 displays individual-level and environmental-level covariate frequencies by fall history, physical performance, and fear of falling. Notably, among those reporting at least a fall in the 12 months preceding data collection, a higher proportion of participants were female and from Kingston or Manizales. While participants from Kingston reported falls more frequently than any other site, relatively few had low SPPB scores and the frequency of those reporting low fear of falling was higher than all sites except St. Hyacinthe. Manizales, in contrast, had relatively few participants reporting low fear of falling compared to the other sites. Both low SPPB and fear of falling were more frequent among women than men and among those with low educations. While there was a greater proportion of the older age group with low SPPB scores, their proportions were lower in the no fall history and low fear of falling categories. The participants frequently reported uneven sidewalks, but the proportion was smallest among those with a low fear of falling. The low fear of falling group also reported the fewest community barriers and highest perceived safety.

Table 1. Individual and environmental level covariates fall history, physical performance, and fear of falling

	Fall History, *N=1985*		SPPB, n(%), *N=1998*		Fear of Falling, n(%), *N=1992*		
	No (N=1430)	Yes (N=555)	>=8 (N=1735)	<8 (N=263)	Low (N=892)	Medium (N=645)	High (N=455)
Sex, *n(%)*							
Male	720(50.4)	225(40.5)	863(49.7)	90(34.2)	538(60.3)	279(43.3)	133(29.2)
Female	710(49.7)	330(59.5)	872(50.3)	173(65.8)	354(39.7)	366(56.7)	322(70.8)
Age, *n(%)*							
64-69	782(54.7)	312(56.2)	989(57.0)	114(43.4)	533(59.8)	343(53.2)	224(49.2)
70-74	648(45.3)	243(43.8)	746(43.0)	149(56.7)	359(40.3)	302(46.8)	231(50.8)
Education, *n(%)*							
High	378(26.4)	179(32.3)	512(29.5)	48(18.3)	281(31.5)	190(29.5)	89(19.6)
Medium	487(34.1)	173(31.2)	576(33.2)	88(33.5)	280(39.4)	214(33.2)	167(36.7)
Low	565(39.5)	203(36.6)	647(37.3)	127(48.3)	331(37.1)	241(37.4)	199(43.7)
Uneven Sidewalk, *n(%)*							
Yes	986(71.9)	386(72.5)	1180(70.8)	199(80.6)	554(65.3)	452(73.0)	369(83.9)
No	386(28.1)	145(27.5)	486(29.2)	48(19.4)	294(34.7)	167(27.0)	71(16.1)
Community Barrier Scale, *x* ± SD[a]	7.0(2.0)	6.6(2.0)	6.7(2.0)	7.7(1.4)	6.5(2.1)	6.9(1.9)	7.5(1.6)
Perception of Safety, *mean(SD)*[b]	20.8(3.8)	20.5(3.7)	20.9(3.7)	19.4(4.2)	21.8(3.0)	20.4(3.9)	19.1(4.3)
Site Location, *n(%)*							
Kingston	240(16.8)	154(27.8)	369(21.3)	27(10.3)	218(24.4)	130(20.2)	46(10.1)
St. Hyacinthe	309(21.6)	91(16.4)	376(21.7)	25(9.5)	283(31.7)	89(13.8)	28(6.2)
Tirana	318(22.2)	69(12.4)	314(18.1)	78(29.7)	200(22.4)	106(16.4)	84(18.5)
Manizales	267(18.7)	136(24.5)	364(21.0)	43(16.4)	57(6.4)	184(28.5)	165(36.3)

Natal	296(20.7)	105(18.9)	312(18.0)	90(34.2)	134(15.0)	136(21.1)	132(29.0)

Missing values-- Fall History: n=17, SPPB: n=3, Fear of Fall: n=10, Uneven Sidewalk: n=85, Community Barrier Scale: n=47, Perception of Safety: n= 110, Average Minutes Walking per Day: n=80

[a]Community barrier scale ranges from 3 to 9, higher score indicates more community barriers

[b]Perception of safety scale ranges from 8 to 24, higher score indicates higher perceived safety

In Table 2, the outcome measure, average minutes walking per day, is displayed by fall history, physical performance, fear of falling, and covariates. The results are stratified by site location to depict site-specific differences. Individuals with higher physical performance, lower fear of falling, who are males, with higher education, and who are younger walked significantly more. For site location, the highest average daily walking time was in Kingston (m=38.3), followed by Tirana (m=35.6), St. Hyacinthe (m=29.5), Manizales (m=28.3), and Natal (m=16.8). Although not statistically significant with all sites combined, there was a significant difference in walking time by fall history in Tirana and uneven sidewalks in Kingston. In Tirana, individuals who had not fallen within the past 12 months had higher mean daily walking minutes (m=37.8) compared to those who reported a recent fall (m=24.6). In Kingston, individuals who reported having uneven sidewalks in their neighborhoods walked more (m=43.1) compared to individuals who reported no uneven sidewalks (m=30.5). Those who perceived low community barriers had the highest daily mean walking minutes (m=33.6), followed by high barriers (m=29.1) and middle barriers (m=25.3). Those with middle levels of perceived safety had the highest daily mean walking minutes (m=33.8), followed by high perceived safety (m=31.2) and low perceived safety (m=24.5).

Table 2. Average minutes walking per day by fall history, physical performance, fear of falls, and covariates, stratified by site location

Average Minutes Walking per Day, *x(SD)*	All sites, *N=1922*	Kingston, *N=374*	St. Hyacinthe, *N=355*	Tirana, *N=387*	Manizales, *N=404*	Natal, *N=402*
Fall History						
No	30.6(30.7)	41.9(3.2)	29.5(2.6)	37.8(2.1)*	27.9(1.8)	17.8(1.2)
Yes	26.6(32.6)	32.7(2.9)	29.3(3.8)	24.6(3.5)	29.2(3.1)	13.9(1.8)

SPPB						
>=8	31.9(37.0)*	39.4(2.3)	30.6(2.3)*	40.3(2.1)*	30(1.7)*	18.7(1.2)*
<8	13.4(24.0)	24.9(9.3)	13.5(3.0)	16.9(3.1)	12.8(2.5)	10.3(1.6)
Fear of Falling						
Low	36.0(41.0)*	44.2(3.2)*	32.2(2.9)	43.8(2.9)*	29.5(3.5)*	21.5(2.0)*
Medium	29.2(33.1)	34.6(3.7)	25.2(3.1)	34.8(3.1)	32.1(2.7)	18.5(1.7)
High	17.7(24.3)	22.7(5.7)	16.2(3.5)	16.1(2.2)	23.3(2.1)	10.4(1.2)
Uneven Sidewalk						
No	32.5(33.7)	30.5(2.9)*	30.7(3.1)	39.9(3.2)	33.6(3.1)	10.3(2.6)
Yes	28.5(36.3)	43.1(3.2)	28.8(3.2)	34.0(2.3)	26.4(1.8)	17.5(1.0)
Sex						
Male	33.7(1.2)*	39.4(3.4)	32.9(2.8)*	44.5(3.1)*	31.1(2.2)	21.8(1.7)*
Female	25.7(1.1)	37.4(3.0)	26.5(3.2)	27.7(2.1)	25.6(2.2	12.4(0.9)
Age						
64-69	31.9(1.2)*	40.0(3.2)	32.4(3.0)	40.1(2.8)*	30.4(2.3)	17.0(1.4)
70-74	26.6(1.1)	36.2(3.1)	24.4(2.8)	31.2(2.4)	25.9(2.2)	15.6(1.3)
Education						
High	34.8(1.6)*	36.6(3.7)	35.3(3.3)	43.8(4.2)*	40.6(3.8)*	20.8(2.2)*
Medium	27.8(1.5)	37.5(4.2)	28.3(5.7)	33.8(3.1)	25.3(2.1)	15.0(1.5)
Low	27.3(1.2)	40.1(3.7)	28(2.7)	31.6(2.5)	21.2(2.1)	15.8(1.5)
Community Barrier Scale[a]						
Low	33.6(1.4)*	39.9(2.5)	29.1(1.8)	31.2(8.2)	31.2(3.0)	19.3(2.6)
Middle	25.3(1.6)	26.6(5.7)	34.9(8.8)	33.5(4.7)	29.4(2.4)	17.0(1.4)
High	29.1(1.4)	35.6(11.0)	25.5(8.5)	36.5(2.1)	24.6(3.0)	16.4(1.6)
Perception of Safety[b]						
High	31.2(1.6)*	40.1(3.9)	30.2(2.8)	33.2(2.6)	20.2(2.2)*	11.9(4.8)
Middle	33.8(1.5)	34.8(3.2)	34.1(5.0)	37.0(2.6)	34.5(3.2)	18.8(2.9)
Low	24.5(1.2)	37.6(4.3)	24.7(4.3)	41.3(6.3)	28.2(2.4)	16.5(1.1)
Site Location						
Kingston	38.3(43.6)*	---	---	---	---	---
St. Hyacinthe	29.5(40.7)	---	---	---	---	---
Tirana	35.6(36.8)	---	---	---	---	---
Manizales	28.3(31.8)	---	---	---	---	---
Natal	16.8(19.8)	---	---	---	---	---

**One-way ANOVA test of difference in average walking time for the whole sample and by each study site, p <0.05.*

Missing values-- Fall History: n=17, SPPB: n=3, Fear of Fall: n=10, Uneven

Sidewalk: n=31

[a]CBS reported by tertiles with all site combined, low indicates low levels of perceived community barriers

[b]PoSS reported by tertiles with all sites combined, high indicates high levels of perceived safety

Table 3 displays the results of four mixed-effects models clustered by site location, along with the ICC for each model. Model coefficients and 95% confidence intervals are exponentiated for easier interpretation. In Model 1, only SPPB and fear of falls are significant correlates to average minutes walking per day. Estimated walking minutes are 52% lower for those with low SPPB compared to high SPPB, 20% lower for those with medium level fear of falling compared to low levels, and 50% lower for those with high level fear of falling compared to low levels. There was little change observed in coefficients and confidence intervals for principal exposures across the four models. In Model 3, which included only perceived environmental-level factors, high CBS was associated with less walking compared to low barriers, and middle PoSS was associated with more walking compared to high-perceived safety. The ICC is presented at the bottom of each model and is a measure of the total variance in walking time that is attributable to clustering by study site. The ICCs for all models were low (less than 0.06) Thus, less than 6% of the variation in walking time can be attributed to how individuals within site resemble each other.

Table 3. Mixed linear regression models for geometric mean minutes walking for reference group, ratio of geometric mean minutes by principal exposures, individual-level exposures, and perceived environmental level exposures clustered by site location

		Model 1		Model 2		Model 3		Model 4	
		β	95% CI	β	95% CI	β	95% CI	β	95% CI
Principal exposures	Fall History								
	No	1.00		1.00		1.00		1.00	
	Yes	0.99	0.87-1.13	0.97	0.86-1.11	0.94	0.83-1.08	0.93	0.82-1.06
	SPPB								
	>=8	1.00		1.00		1.00		1.00	

	<8	0.48*	0.39-0.57	0.49*	0.41-0.59	0.50*	0.41-0.61	0.51*	0.42-0.61
	Fear of Falling								
	Low	1.00		1.00		1.00		1.00	
	Medium	0.80*	0.70-0.92	0.85*	0.74-0.97	0.82*	0.71-0.86	0.86*	0.74-0.99
	High	0.50*	0.42-0.59	0.55*	0.46-0.65	0.51*	0.42-0.61	0.56*	0.47-0.67
Individual-level	Sex								
	Male	--		1.00		--		1.00	
	Female	--		0.83*	0.74-0.93	--		0.84*	0.75-0.95
	Age								
	64-69	--		1.00		--		1.00	
	70-74	--		0.89*	0.79-0.99	--		0.88*	0.79-0.99
	Education								
	High	--		1.00		--		1.00	
	Medium	--		0.78*	0.67-0.90	--		0.76	0.66-1.13
	Low	--		0.81*	0.70-0.93	--		0.84*	0.72-0.96
Environmental-level	Uneven Sidewalk								
	No	--		--		1.00		1.00	
	Yes	--		--		1.01	0.88-1.16	1.01	0.88-1.16
	Community Barrier Scale[a]								
	Low	--		--		1.00		1.00	
	Middle	--		--		0.88	0.74-1.04	0.88	0.74-1.05
	High	--		--		0.79*	0.65-0.96	0.81*	0.67-0.97
	Perception of Safety[b]								
	High	--		--		1.00		1.00	
	Middle	--		--		1.21*	1.02-1.44	1.22*	1.03-1.45
	Low	--		--		1.12	0.97-1.31	1.10	0.95-1.28
	ICC	**0.04**		**0.04**		**0.06**		**0.06**	

ICC= Intraclass correlation coefficient, low ICC is <0.4

**p<0.05*
[a]CBS reported by tertiles with all site combined, low indicates low levels of perceived community barriers
[b]PoSS reported by tertiles with all sites combined, high indicates high levels of perceived safety

Discussion

Using the socioecological model, we examined the role of individual-level and perceived environmental-level exposures on the relationship between falls, fear of falling, and physical performance (SPPB) on walking. This study is one of the first to examine multilevel factors using cross-national data. Fall history was not associated with walking times, but SPPB and fear of falling were associated with them. Although individual and environmental level factors such as sex, age, education, CBS, and PoSS had a significant relationship with minutes walking in all 4 models, these individual and environmental factors had little influence on the relationship between the principal exposures and outcome. In other words, the relationship between fall history, fear of falling, and SPPB on walking did not change despite adding individual and environment level factors into the models. These findings reflected Davis et al.'s findings that, within middle income countries, individual and interpersonal level factors were associated with older adults meeting physical activity guidelines, and not community or organizational level factors [24].

As expected, lower physical performance and higher fear of falling were associated with less walking time. The relationship between these variables remained relatively constant even with the addition of individual and environmental level covariates. Although this study did not identify the causal pathway of these variables, it supports the results of previous studies that observed similar variables separately. Cooper et al is of the many authors who demonstrated that increased physical activity levels improve physical performance and other health outcomes [25]. Delbere et al demonstrated that fear-related avoidance of physical activity in Belgium could have negative effects on physical ability due to the lack of physical activity and training [8]. Surprisingly, fall history (whether the individual has experienced falls), was not associated with minutes walking in all four models. Based on previous studies, fall history was expected to influence minutes walking. One explanation may be that the difference in culture, government structure, and health policies among the different high and middle income sites affect and cancel out the relationships observed between the variables. Although the low ICC in the mixed models clustered by site suggests low influence from the site, bivariate analysis shows that the high income site, Kingston, has the highest proportion of those who reported falls history, yet the lowest proportion of those who have high fear of falling. The opposite was observed in Tirana. One explanation could be that illness is often overreported in higher income households. For example, an individual with higher income and education, who is generally healthy most of the time, may be able to identify if she or he is ill more than an individual with lower income and education [26]. Furthermore, Foster argues that higher income individuals have the means to dampen the impacts of poor health, whereas lower income individuals do not, thus the impacts of poor health should be observed more closely among lower income individuals.

In model 3 with only individual level covariates, female sex, older age group, and lower education were associated with less walking time. A study of older adults conducted in Australia by Booth et al. yielded similar results. Although falls were not incorporated into Booth's study, Booth et al. concluded that PA was sex and age dependent. That is, males and younger age groups were more active [27]. It is well established that socioeconomic status plays a role in health behaviors and outcomes. Therefore, it is not surprising that lower education was associated with less walking time. In the model with only environmental level factors (i.e. Model 3), the indicator, uneven sidewalks, was surprisingly not significantly associated with walking. PA literature has repeatedly demonstrated the importance of the built environment, such as having uneven sidewalks, on PA outcomes [28]. Perhaps since uneven sidewalks is a self-reported measure, only those who are regularly physically outdoors notice uneven sidewalks. Bivariate analysis results in Table 2 show that the relationship between CBS and walking is not linear. This was confirmed in the multivariate model when only high CBS was associated with less walking compared to low CBS. These results broadly corroborate with other studies that show community barriers, such as lack of access to public areas decreases older adult PA behavior [29]. The non-linear relationship seen in this study may suggest that there is a threshold of community barriers that need to be met before having a negative impact on walking. Future studies should examine whether or not the amount and type of community barriers might determine walking. Similar to CBS, PoSS did not have a linear relationship with walking. Unexpectedly, middle levels of PoSS were associated with higher levels of walking. Although not statistically significant, it should be noted that low levels of PoSS were also associated with higher levels of walking compared to high levels of PoSS. This was not the result we expected. PoSS aims to measure environmental safety and possible social distress from the neighborhood. Previous studies have demonstrated that people living neighborhoods with high levels of social disorganization are not willing to recognize the negative aspects of their neighborhood due to feelings of community belonging. While another possible explanation for why middle levels of PoSS had higher minutes of walking compared to high levels is that we might be capturing walking for occupational or transportational purposes instead of leisure. In which case, these needs may outweigh the safety concerns [30, 31]. This study focused on walking since it was a common PA recommendation for older adults. Since PA done for leisure is associated with better health outcomes compared to occupational PA [32], it may be worthwhile to expand further the definition of walking.

When comparing the effects of the environment versus individuals, different studies have contrasting results from each other. A study conducted in Australia showed that the effects of physical environment was not as strong as the effects of individual characteristics [33]. The physical environment supports and enhances PA in complement with individual characteristics and social environment. Conversely, a study conducted in the United States showed that physical environment played a stronger role in determining PA compared to individual traits [34]. Results from this study support the notion that environmental and indivdiual factors influence minutes walking. Although both environmental and individuals level factors seem to play a role in determining minutes walking, adding them to the models did not affect the relationship of falls, fear of falling, and SPPB on walking, or, as observed in Model 4 (Table 3) with each other. This may suggest that cross-national health promotion efforts can increase walking among older adults by addressing their fear of falling and improving physical performance.

Strengths & Limitations

This study takes into account environmental and individual level factors to PA in a cross-national sample of participants from middle and high income countries. The analysis strategy applied to this study was grounded in a well-established theoretical foundation, the socioecological model. Four mixed-effects models were used to test the interactions between individual and environmental level factors. A nested model was used based on the theory that was applied. Despite sampling from four very different study sites, the variance of walking was not due primarily to study site, or geographical location. Instead, SPPB and fear of falling, along with other individual characteristics such as sex, were strong predictors.

While their study has many strengths, there are limitations too. First, we are unable to determine etiology with a cross-sectional data set. However, since the benefits of walking for older adults are well-established, the purpose of this paper was to identify any correlates to walking that can potentially be of public health value. Second, the accuracy of the self-reported environmental exposures may affect the results. Participants would have to be outdoors in order to accurately report environmental factors, CBS and PoSS. If participants are already outdoors, then they may already be engaging in PA. Furthermore, there might be a possibility of misclassification error as mentioned in the discussion above. Nonetheless, studies have shown that the perceived environment is a stronger predictor of PA compared to objective environment (20). Lastly, although the effects of site location have been statistically accounted for, examining the relationship between safety and walking may be a bit more complicated and depend on unmeasured factors unaccounted for in this study. For instance, theoretically speaking, sex and gender play a role in how an individual perceives their environmental safety [35].

Conclusion

Many older adults remain or become increasingly physically inactive over time. An individual's fall concern and physical performance may be important to consider when making recommendations to increase PA; however, fall history doesn't seem to affect minutes walking. Individual and environmental level factors do not seem to affect the relationship. Identifying and addressing barriers to PA in older adults may be useful for health care practitioners and health policy advocates to generate a multifaceted, multilevel targeting interventions.

Declarations

Ethics approval and consent to participate

All methods were carried out in accordance to the guidelines and regulations set by the ethical committees per prospective site. Ethical approval for this project was obtained from the ethics review committees of the research centers of the University of Montreal Hospitals (CR-CHUM), Queen's University (Kingston), the Albanian Institute of Public Health, the Federal University of Rio Grande do Norte (Brazil) and the University of Caldas (Colombia). Informed consent was obtained from participants prior to the start of the study. No participants under 18 years of age were included in this study.

Consent for publication

Consent to publish unidentifiable data was obtained from participants.

Availability of data and materials

The results/data/figures in this manuscript have not been published elsewhere, nor are they under consideration (from you or one of your Contributing Authors) by another publisher. All of the material is owned by the authors and/or no permissions are required. I am the author responsible for the submission of this article and I accept the conditions of submission and the BMC Copyright and License Agreement as detailed above. The study materials are available in table form in this paper.

Competing interests

No, I declare that the authors have no competing interests as defined by BMC, or other interests that might be perceived to influence the results and/or discussion reported in this paper.

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Authors' contributions

P.W.H. was lead on the paper. She conceptualized the paper, wrote the manuscript text, analyzed data, and finalized the tables. M.A. conceptualized the paper and assisted with writing and data analysis. A.V. assisted with data analysis and tables. N.T.A.R assisted with data analysis and summary. Y.Y.W. provided biostatistics support and assisted with data summary. C.M.P. oversaw the project.

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