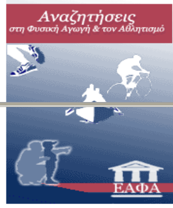
Research



Inquiries in Sport & Physical Education
Volume 21 (1), 49 – 60
Released: July 2023

Αναζητήσεις στη Φυσική Αγωγή & τον Αθλητισμό
Τόμος 21 (1), 49 – 60
Δημοσιεύτηκε: Ιούλιος 2023

www.pe.uth.gr/emag

ISSN 1790-3041

Fear of falls and moderate-to-vigorous physical activity in community-dwelling older adults. A cross-sectional analysis

[1]Archontissa M. Kanavaki, [1]Maria Michalopoulou, [1]Evgenia Kouli, [1]Athanasios Gkrekidis, [1]Helen T. Douda, [1]Ilias Smilios, [1]Vasilios Gourgoulis, [2]Georgios Ch. Sirakoulis, [1]Nikolaos Aggelousis

[1]Department of Physical Education and Sport Science, Democritus University of Thrace
[2]Department of Electrical and Computer Engineering, Democritus University of Thrace

Abstract

Physical activity guidelines for older adults include at least 150 minutes of moderate-to-vigorous aerobic physical activity (MVPA) per week. Fear of falling (FoF) is common among community-dwelling older adults and can lead to activity restriction in daily living and in turn, increased fall risk. Given the limited evidence linking FoF with accelerometer-assessed MVPA, the present study aimed to examine the association of FoF with MVPA controlling for key confounders, including physical function, fall history and unsteady gait. A total of 149 community-dwelling individuals ≥60 years (Mean age=72.10±6.23, 84.6% women) completed a set of self-report and physical performance measures and wore a triaxial accelerometer for a week. Multivariate linear regression models examined the association between FoF and MVPA adjusting for potential confounders. In the fully adjusted model, 28.2% of the variance in MVPA was explained by the predictors (F_{change}=4.97, p<.01) and high FoF was significantly associated with fewer minutes/week of MVPA (β=-12.33, BCaCIs[-19.89, -4.32]). Findings revealed that among the multiple factors associated with MVPA in older adults, FoF has a small, yet significant influence. Identifying older adults with high FoF and addressing these concerns, should be part of the agenda of exercise and other professionals working with older adults, as this could promote a more active lifestyle and reduce fall risk in this population.

Keywords: *fear of falling, moderate-to-vigorous physical activity, accelerometer, older adults, physical function*

Corresponding address: Archontissa Kanavaki
Department of Physical Education and Sports Sciences, Democritus University of Thrace
69100, Komotini, Greece
E–mail: mkanavak@affil.duth.gr

Ερευνητική

Φόβος Πτώσης και Φυσική Δραστηριότητα Μέτριας-προς-Έντονης Έντασης σε Άτομα Τρίτης Ηλικίας. Μια Συγχρονική Έρευνα

[1]Αρχόντισσα Μαρία Καναβάκη, [1]Μαρία Μιχαλοπούλου, [1]Ευγενία Κούλη, [1]Αθανάσιος Γκρεκίδης, [1]Ελένη Δούδα, [1]Ηλίας Σμήλιος, [1]Βασίλειος Γούργουλης, [1]Γεώργιος Συρακούλης, [1]Νικόλαος Αγγελούσης

[1]Τμήμα Επιστήμης Φυσικής Αγωγής και Αθλητισμού, Δημοκρίτειο Πανεπιστήμιο Θράκης
[2]Τμήμα Ηλεκτρολόγων Μηχανικών και Μηχανικών Υπολογιστών, Δημοκρίτειο Πανεπιστήμιο Θράκης

Περίληψη
Οι συστάσεις για φυσική δραστηριότητα σε άτομα τρίτης ηλικίας περιλαμβάνουν 150 λεπτά/εβδομάδα μέτριας-προς-έντονης έντασης αερόβια φυσική δραστηριότητα (ΜΕΦΔ). Από την άλλη πλευρά, ο φόβος πτώσης συναντάται συχνά σε άτομα τρίτης ηλικίας και μπορεί να οδηγήσει σε περιορισμό της καθημερινής φυσικής δραστηριότητας και, κατ΄ επέκταση, σε αυξημένο κίνδυνο πτώσης. Δεδομένου ότι περιορισμένος αριθμός ερευνών έχει εξετάσει τη σχέση φόβου πτώσης με τη ΜΕΦΔ, όπως μετράται με επιταχυνσιόμετρα, η παρούσα έρευνα είχε στόχο να εξετάσει την παραπάνω σχέση λαμβάνοντας υπόψη τρίτους παράγοντες που μπορεί να επηρεάζουν τη σχέση αυτή, όπως η λειτουργικότητα, το ιστορικό πτώσεων και η αστάθεια στη βάδιση. Στο σύνολο 149 άτομα ≥60 ετών (Μ.Ο. ηλικίας=72.10±6.23, 84.6% γυναίκες) που διαβιούσαν αυτόνομα πήραν μέρος στην έρευνα, που περιελάμβανε μετρήσεις με ερωτηματολόγια, τεστ φυσικής κατάστασης και χρήση επιταχυνσιομέτρου για μία εβδομάδα. Πολυπαραγοντικά μοντέλα γραμμικής παλινδρόμησης εξέτασαν τη σχέση του φόβου πτώσης με την ΜΕΦΔ ελέγχοντας για την επίδραση τρίτων μεταβλητών που αξιολογήθηκαν. Στο τελικό μοντέλο, οι προβλεπτικοί παράγοντες εξηγούσαν το 28.2% της μεταβλητότητας της ΜΕΦΔ (F_{change}=4.97, p<.01). Τα υψηλά επίπεδα φόβου πτώσης εμφάνιζαν σημαντικά αρνητική σχέση με την ΜΕΦΔ (β=-12.33, BCaCIs[-19.89, -4.32]).Τα ευρήματα αυτά δείχνουν ότι ο φόβος πτώσης έχει μικρή αλλά σημαντική συνεισφορά στην καθημερινή ΜΕΦΔ των ατόμων τρίτης ηλικίας. Η αξιολόγηση του φόβου πτώσης και η αντιμετώπισή του σε άτομα τρίτης ηλικίας που εμφανίζουν υψηλά επίπεδα από επαγγελματίες άσκησης, υγείας κλπ., θα μπορούσε να βοηθήσει στην προαγωγή της φυσικής δραστηριότητας και τη μείωση πτώσεων σε αυτόν τον πληθυσμό.

Λέξεις-κλειδιά: *φόβος πτώσης, μέτρια-προς-έντονη φυσική δραστηριότητα, επιταχυνσιόμετρο, τρίτη ηλικία*

Διεύθυνση επικοινωνίας: Αρχόντισσα Καναβάκη
Τμήμα Επιστήμης Φυσικής Αγωγής και Αθλητισμού, Δημοκρίτειο Πανεπιστήμιο Θράκης
ΤΚ 69100, Κομοτηνή, Ελλάδα
E–mail: mkanavak@affil.duth.gr

Introduction

Fear of falling (FoF) is a term referring to psychological concerns around falling. Common definitions comprise fall-related concerns and fall-related self-efficacy (i.e., balance confidence) (Hadjistavropoulos et al., 2010). A large share of older adults experience FoF, with various studies worldwide reporting proportions from 24% to 59.1% (Choi & Ko, 2015; Mendes da Costa et al., 2012; Murphy et al., 2002; Vitorino et al., 2019). FoF shows consistent and strong associations with worse perceived quality of life in older adults, as revealed by a systematic review of 30 studies in 30.000 participants (Schoene et al., 2019).

A key negative effect of FoF in older adults is restriction or avoidance of activities in their daily living, which serves as a protective strategy against falls. Fear-related activity restriction is commonly reported by older adults (19%-35%) (Choi & Ko, 2015; Fletcher et al., 2010; Mendes da Costa et al., 2012; Murphy et al., 2002; Vitorino et al., 2019). This can lead to physical deconditioning and increased fall risk (Hadjistavropoulos et al., 2010). For example, in a recent study based on two large nationally representative samples in the US, older adults who limited their activities due to FoF had worse balance and greater fall risk, an effect which remained significant after adjusting for physical function (Garbin & Fisher, 2023a). In another prospective cohort study with 673 community-dwelling older adults, more than 70% of participants developed moderate or severe FoF-related activity restriction over the 3-year follow-up, which in turn was a significant predictor of disability in daily living (Deshpande et al., 2008). FoF has also been connected to reduction in life space across different cultural and social settings (Auais et al., 2017).

FoF, activity avoidance, physical function and falls are linked to each other, as well as other factors, in a complex interplay (Schoene et al., 2019; Wijlhuizen et al., 2008). For example, fall history, namely having sustained one or more falls, FoF and feeling unsteady when walking are criteria for identifying older adults at fall risk (Hnizdo et al., 2013; Stevens, 2013). Both fall history and poor physical function, especially balance-related, are associated with higher levels of FoF and fear-related activity restriction (Bertera & Bertera, 2008; Choi & Ko, 2015; Denkinger et al., 2015; Fletcher et al., 2010; Murphy et al., 2002). The effect of FoF on fall risk is significant above and beyond that of balance performance (Garbin & Fisher, 2023b) and may even explain a larger proportion of fall risk than balance performance (Landers et al., 2016), yet balance is also negatively affected when anxiety increases (Carpenter et al., 2006). Self-reported unsteadiness was an independent predictor of fear-related activity restriction, incidence of falls and physical disability over the course of two years in a large population-based study (Donoghue et al., 2017). Lastly, associations of female gender with FoF, activity restriction and fall risk have also been established (Denkinger et al., 2015; Fletcher et al., 2010; Gazibara et al., 2017; Mendes da Costa et al., 2012; Vitorino et al., 2019).

The above interplay bears particular significance when it comes to the promotion of physical activity (PA) in older adults. The recommended aerobic activity for this age group is a minimum of 150 minutes of moderate-to-vigorous PA per week (MVPA), irrespective of accumulation pattern, for health and well-being benefits (Bull et al., 2020; U.S. Department of Health and Human Services, 2018). However, evidence regarding the association of MVPA with fall risk in older adults is mixed, even in literature utilising device-measured PA (Gregg et al., 2000; Ramsey et al., 2022). For example, a large cohort study did not find associations between accelerometer-measured MVPA and rate of falls controlling for physical function (Buchner et al., 2017), whereas another found a positive association between the above two variables, but only among participants without (self-report) mobility limitations (Jefferis et al., 2015). Combinations of different PA levels and physical function may have differential effects on fall risk, with those in high PA-low physical function having the highest fall risk (Lewis et al., 2016). On the other hand, a recent systematic review reported a positive relationship between FoF and device-measured PA in community-dwelling older adults (Ramsey et al., 2022). In this review, studies on FoF operationalised PA mainly as steps or total PA, i.e., without taking intensity into account, and it is unclear whether physical function was adjusted for.

It has been proposed that addressing FoF should be part of interventions aiming to support physical function and independent living in older adults (Deshpande et al., 2008) and that balance training alone may not be sufficient for fall prevention (Garbin & Fisher, 2023b). Given that low MVPA levels could be a proxy variable for activity restriction, which is not often assessed in FoF-focused studies (Schoene et al., 2019), understanding the degree to which FoF is associated with MVPA in older adults could inform interventions for fall prevention and PA promotion as to target mechanisms, e.g., improvement of balance/ physical function or also addressing FoF. The present study aimed to examine the association of FoF with MVPA controlling for physical function and fall risk factors, namely fall history, feeling unsteady when walking, age and gender. We hypothesised that FOF has an inverse association with MVPA and that this association will still be significant, albeit weaker, after controlling for these confounding factors.

Methods

Participants

A total of 149 individuals, ≥60 years, residing in the prefecture of Rodopi, who could ambulate independently or with the help of a walking stick, took part in the study. Exclusion criteria were any cognitive or physical/ health impairment or language barrier (non-fluent Greek speakers) which would prevent individuals from completing the assessments. Participants were recruited via local community centres, social services, cultural associations, adverts and word of mouth; hence it was a convenience sample.

Instruments

Self-reported

Fall history and unsteady gait. Single item questions with yes/no responses assessed 1) fall history, i.e. fall incidence in the past 12 months; 2) whether the participant felt unsteady when walking.

Fear of falling was assessed by the Falls Efficacy Scale-International (FES-I) which assesses concerns about falling during 16 common activities of daily living, on a 4-point scale ("*not at all*" to "*very*" concerned) (Yardley et al., 2005). English and Greek versions both have good psychometric properties (Billis et al., 2011; Yardley et al., 2005). Cronbach's *a* for the present study was .90. The recommended cut-off points were applied to the summed score to categorise individuals in low (16-19), moderate (20-27) and high (28-64) FoF.

Depressive symptoms. The 15-item Geriatric Depression Scale (GDS) is an accurate tool for assessing depression in older adults (Park & Kwak, 2021; Yesavage & Sheikh, 1986). Cronbach's *a* was .77 for the present study. Its responses are yes/no and a score of ≥6 signifies depression (Fountoulakis et al., 1999). Its use in assessing risk of falling is also recommended (Lusardi et al., 2017).

Socio-demographic characteristics. Participants' age, gender, education, marital and cohabitation status were recorded.

Physical performance

Balance-related physical function was assessed with the 8ft Timed Up-and-Go (TUG) from the Senior Fitness Test, a well-established measure of physical function in the elderly with good psychometric properties (Rikli & Jones, 1999).

Physical activity

Actigraph accelerometers GT9X and GT3X (Actigraph, LLC., Pensacola, Florida, USA), waist-worn were used for PA assessment. The triaxial lightweight devices recorded accelerations in the default frequency of 30Hz, which were analyzed in 60-second epochs. Data was considered valid if having at least four days of 10h/day wear-time. Non-wear time was excluded from the analysis (Choi et al., 2011). To classify PA intensity, cut-points validated for older adults were applied on vector magnitude counts per minute (cpm), i.e. ≥2751cpm for MVPA, 201-2750cpm for light PA (LPA), ≤200cpm for sedentary time (Aguilar-Farías et al., 2014; Santos-Lozano et al., 2013).

Anthropometric

Height (cm) was measured using a stadiometer. Weight (kg) was measured using a digital scale and Body Mass Index (BMI) was calculated with the same digital scale after entering height.

Procedure

The study has received ethical approval from the Research Ethics Committee of Democritus University of Thrace (DUTH/EHDE/28061/165) and complies with ethical practices. Eligible individuals were identified from member lists of local community centres, cultural associations etc. and were invited by a member of staff/board to take part in the study. Adverts and word of mouth were also used and those interested could contact the research team directly and book an appointment. Verbal information and a Participant Information Sheet were provided and Informed Consent was signed prior to data collection. Data collection took place at the local centre, where participants completed an interview-administered questionnaire pack, anthropometric measures and physical function performance tests. Sample size calculations were based on a minimum of 119 cases required to detect a medium effect (R^2=0.13) in a multivariate regression model with 10 predictors with a .80 power and significance of .05 (Field, 2018).

Data Analysis

Data analysis was conducted using SPSS version 27.0. Only participants who had valid accelerometer data were included in the analysis. Missing data in scale calculation were handled as per scale instructions or allowing up to 20%. Assumptions of linearity, normality, independence and equality of variance, as well as multicollinearity among regression model variables were tested (Field, 2018). Due to high skewness in MVPA, bootstrap method bias corrected and accelerated (i.e., robust regression) was applied (Field, 2018). T-tests compared time in MVPA for binary variables and bivariate correlations among MVPA and continuous variables were tested. One-way ANOVA tested differences in MVPA among participants at low, medium and high levels of FoF. A multivariate linear regression was conducted to examine the association between FoF and MVPA adjusting for potential confounders (enter method). Confounders were selected based on their associations with MVPA found in existing literature and/or in the present study. Model 1 was adjusted for age, sex and LPA (step 1). FoF was entered as categorical (dummy) variables indicating "high" and "medium" FoF (step 2). Model 2 was additionally adjusted for fall risk criteria, namely fall history and feeling unsteady when walking (step 2) and balance-related physical function, i.e., TUG (step 3), before entering FoF (step 4).

Results

A total of 149 individuals were included in the analysis. Among participants 84.6% were women, 50.4% had primary and 18.4% tertiary education. Also, 64.4% of participants were married and 28.9% widowed. 75% of participants were co-habiting with a family member. Participant characteristics for continuous variables are presented in Table 1. With regard to falls-related factors, 44.30% and 28.19% of participants reported moderate and high FoF respectively, 34.5% of participants reported having a fall in the past 12 months, whilst 30.2% were feeling unsteady when walking. Also, 19.4% of participants had depressive symptoms.

Table 1. Descriptive statistics for the study variables (continuous).

	Mean (±SD)			
	Total	High FoF	Moderate FoF	Low FoF
Age (years)	72.10 (±6.23)	72.67 (±6.62)	71.74 (±6.36)	72.10 (±5.69)
Education (years)	9.16 (±4.21)	8.92 (±6.62)	8.91 (±3.98)	9.80 (±4.77)
BMI(kg/m)	31.41 (±5.01)	32.38 (±5.17)	32.24 (±6.08)	30.47 (±2.95)
TUG (sec)	7.38 (±2.70)	8.25 (±4.22)	7.36 (±1.86)	6.48 (±1.24)
MVPA (daily min)	20.57 (±18.77)	13.50 (±12.74)	20.31 (±17.38)	28.22 (±23.09)
LPA (daily min)	347.19 (±87.11)	339.49 (±84.23)	356.81 (±88.42)	339.83 (±88.55)
Depression (score)	2.78 (±2.70)	3.33 (±7.68)	3.19 (±2.91)	1.61 (±1.50)
Fear of falls (score)	24.91 (±7.95)	34.94 (±7.68)	23.05 (±2.06)	17.67 (±1.02)

N_{High}=42, $N_{Moderate}$=66, N_{Low}=41, FoF=Fear of falling, TUG=Timed Up-and-Go test, MVPA=Moderate-to-vigorous physical activity, LPA=Light physical activity.

There were no significant differences in MVPA between men and women or between participants with/without history of falls. However, participants who felt unsteady when walking engaged in significantly less MVPA (M=14.61, SD=13.20) than those who did not (M=23.15, SD=20.24), $t(124.15)=3.06$, $p<.01$. Participants with depressive symptoms did not differ significantly in MVPA from those without. In the univariate analysis there was a significant effect of FoF on MVPA, $F(2, 146)=6.90$, $p=.001$, $\omega^2=.073$. Post-hoc comparisons using the Games-Howell test indicated that participants with high FoF were engaging in significantly less MVPA

(*M*=13.50, *SD*=12.74) compared to those with low FoF (*M*=28.22, *SD*=23.09). Those with medium FoF did not differ significantly from participants with low and high FoF. There were no significant effects of FoF on LPA and sedentary time. Bivariate correlation between MVPA and BMI was not significant. Other bivariate correlations between continuous variables that were entered in the regression model are presented in Table 2.

Table 2. Bivariate correlations (Pearson's r [95% Cis]) of model variables.

	MVPA	Age	LPA	TUG
1. MVPA	–			
2.Age	-.36***	–		
	[-.47,-.25]			
3. LPA	.23**	-.14	–	
	[.07,.39]	[-.29, .01]		
4.Timed Up-and-Go test	-.33**	.32**	-.08	–
	[-.44, -.28]	[.19, .51]	[-.27, .09]	
5.Fear of falling	-.28**	.14	.01	.48**
	[-.39,-.15]	[-.06,.33]	[-.15, .18]	[.23, .64]

** $p < 0.01$; *** $p < 0.001$, MVPA=Moderate-to-vigorous physical activity, LPA=Light physical activity.

Multivariate hierarchical regressions tested the relationship of FoF with MVPA. Model 1 is presented in Table 3. In Step 1, confounding variables as a group significantly predicted MVPA, accounting for 12.9% of the variance, $F(1,147)=21.79$, $p<.001$. In Step 2, 25.1% of the variance in MVPA was explained by the predictors, $F(2, 142)=7.55$, $p<.001$, with medium and high FoF accounting for 8% of the variance.

Table 3. Multiple linear regression for the change in MVPA in relation to change in FoF adjusting for demographic characteristics.

	b	SE b	Bootstrap for b BCa95% CIs	t	ΔR²	F change
Step 1						
(Constant)	76.68	18.47				
Age	-1.01	.24	[-1.48, -0.55]	-4.34***	.171	9.90***
Sex	2.96	4.15	[-5.24, 11.15]	0.71		
LPA	0.05	0.02	[0.01, 0.08]	2.76**		
Step 2						
(Constant)						
Age	-0.96	0.22	[-1.40, -0.52]	-4.50***	.080	7.50***
Sex	-0.74	4.09	[-8.82, 7.33]	-0.95		
LPA	0.05	0.02	[0.01, 0.08]	2.69**		
Medium FoF	-9.21	3.38	[-15.90, -2.53]	-2.61**		
High FoF	-14.30	3.73	[-21.68, -6.93]	-3.92***		

* $p<.05$, ** $p<.01$, *** $p<.001$, LPA=Light physical activity, FoF=Fear of falling, BCa=Bias corrected and accelerated, CI= Confidence interval.

Results for Model 2 are presented in Table 4. In the full model (step 4), 28.2% of variance in MVPA was explained by the predictors, $F(2, 135)=4.97$, $p=.008$. Age, LPA, TUG (based on CIs) and high FoF were significant predictors, with FoF accounting for a modest 5.3% of the variance after adjusting for confounders. Notably, whilst only high FoF was significant based on the bootstrap method, there was a trend for medium FoF also, as shown by the *p* value .05 in the non-bootstrapped regression model.

Table 4. Multiple linear regression for the change in MVPA in relation to change in FoF adjusting for demographic characteristics, fall risk factors and physical function.

	b	SE b	Bootstrap for b BCa95% CIs	t	ΔR²	F change
Step 1						
(Constant)	79.85	18.35			.167	9.35***
Age	-1.04	.23	[-1.50, -0.58]	-4.45***		
Gender	4.12	4.27	[-4.33, 12.54]	0.96		
LPA	0.04	0.02	[0.01, 0.08]	2.43*		
Step 2						
(Constant)	70.16	18.72			.031	2.63
Age	-0.91	.24	[-1.38, -0.44]	-3.85***		
Gender	4.71	4.35	[-3.90, 13.32]	1.08		
LPA	0.05	0.02	[0.01, 0.08]	2.59*		
Fall history	4.59	3.19	[-1.71, 10.90]	1.44		
Unsteady	-6.76	3.24	[-13.16, -0.36]	-2.09*		
Step 3						
(Constant)	69.84	18.42				
Age	-0.76	0.24	[-1.24, -0.28]	-3.15**	.031	5.56*
Gender	3.98	4.29	[-4.51, 12.47]	0.93		
LPA	0.04	0.02	[0.01, 0.08]	2.46*		
Fall history	3.82	3.15	[-2.42, 10.05]	0.10		
Unsteady	-4.44	3.33	[-11.04, 2.15]	-1.11		
TUG	-1.34	0.57	[-2.47, -0.22]	-2.37*		
Step 4						
(Constant)	75.92	18.13			.053	4.97**
Age	-0.80	0.24	[-1.26, -0.37]	-3.36***		
Gender	2.04	4.24	[-5.40, 10.16]	0.48		
LPA	0.04	0.02	[0.01, 0.08]	2.48*		
Fall history	4.45	3.14	[-1.24, 10.30]	1.14		
Unsteady	-2.56	3.32	[-8.82, 3.45]	-0.77		
TUG	-1.02	0.56	[-2.61, -0.45]	-1.81		
Medium FoF	-6.44	3.45	[-14.40, 1.31]	-1.19		
High FoF	-12.33	3.92	[-19.89, -4.32]	-3.15**		

*p<.05, **p<.01, ***p<.001, LPA=Light physical activity, TUG=Timed Up-and-Go test, FoF=Fear of falling, BCa= Bias corrected and accelerated, CI= Confidence interval.

Discussion

The present study tested the hypothesis that FoF in older adults has a negative association with daily MVPA above and beyond the effects of physical function, fall history, unsteady gait and engagement in lower intensity PA. Notably, a large proportion of participants reported moderate or high FoF (about 44% and 28% respectively), a finding consistent with existing literature (Fletcher et al., 2010; Vitorino et al., 2019). Overall the study findings supported the hypothesis, with FoF remaining a significant MVPA predictor after adjusting for confounders. In the full model, high FoF explained 5.3% of the variance in MVPA (based on robust CIs), whereas in the partial model moderate and high FoF explained 8% of MVPA. Specifically, those experiencing high FoF were engaging in 12.33 minutes less MVPA per day compared to those with low FoF and holding other factors constant. This is a significant amount of MVPA given the whole-sample average of 20.57 minutes/day. Limited evidence exists on the FoF-MVPA relationship and studies utilizing wearables to assess PA mostly focus on total PA irrespective of intensity (Ramsey et al., 2022), despite MVPA being the most beneficial (U.S. Department of Health and Human Services, 2018). Significant associations of device-assessed total daily MVPA with FoF after adjusting for key confounders have been previously reported (Du et al., 2022; Jefferis et al., 2014). This association is also supported by work applying self-report measures of activity restriction (Bertera & Bertera, 2008; Liu et al., 2021; Wu et al., 2023). For example, FoF at baseline was a significant predictor of mobility limitations in outdoor and indoor activities two and four years later, independent of fall history (Liu et al., 2021).

The present findings have some implications for practice. Exercise with a balance element is important for fall prevention and should be recommended to older adults, for example as part of healthcare service (NICE, 2013; Stevens, 2013). There is rationale for including an assessment of FoF, even a brief one, by exercise and other professionals (e.g. social, healthcare) working with older adults, especially for those who face mobility limitations or are predominantly sedentary (Auais et al., 2017; Bertera & Bertera, 2008). Identifying older adults with high FoF and addressing these concerns, in addition to improving physical function with exercise interventions, could be effective for increasing PA, since FoF is a factor independently affecting PA and fall risk (Garbin & Fisher, 2023b; Hadjistavropoulos et al., 2010). There is insufficient evidence that exercise alone can reduce FoF beyond the program end (Kendrick et al., 2014). However, combinations of exercise, education and cognitive behavioural therapy could prove effective for the reduction of FoF (Papadimitriou & Perry, 2020; Parry et al., 2016; Sartor-Glittenberg et al., 2018). For example, elements of cognitive behaviour therapy, such as cognitive restructuring and exposure, could be applied in combination with exercise programs (Wetherell et al., 2016).

Although the current data is cross sectional, findings are in line with the spiralling interactions between FoF, activity restriction and reduction of physical function (leading to disability) in older adults reported in the literature (de Souza et al., 2022; Deshpande et al., 2008; Garbin & Fisher, 2023a). Other factors that were controlled for based on previous work, did not appear significant in the present study, i.e., gender (Denkinger et al., 2015), BMI (Wu et al., 2023), fall history (Bertera & Bertera, 2008) and unsteady gait (Donoghue et al., 2017). It may be that the effects of some of these factors were no longer important when FoF and physical function were included in the models or that these effects were small, while the study was powered to detect medium-size effects.

It is worth noting that overall a modest amount of MVPA variance (28%) was explained by the study variables, hence other factors, not included in the study, influence MVPA behaviours. Indeed, PA determinants are multilevel, from individual-level to the social and physical environment (Sallis & Owen, 2015). Pain, for example, can lead to FoF and fear-related activity avoidance, also impacting falls efficacy (Stubbs et al., 2014; Vlaeyen & Linton, 2000). Psychological factors, such as self-efficacy, are also positively associated with PA behaviours, like walking (Lee et al., 2008; Mullen et al., 2012) and so do social factors. For example, having fewer social contacts has been linked to fear-related activity avoidance (Howland et al., 1998).

Factors assessed in this study were a selection among potential MVPA determinants based on the existing literature on FoF and MVPA, the study resources and scope. As mentioned previously, the study would be under-powered to detect small effect sizes. However, a small effect size probably indicates lack of clinical significance, which would deem the relevant factors inappropriate targets for an intervention with public health interest. Among the study limitations is also the underrepresentation of men in the sample. It appears that women were more actively engaged in local social groups and community centres. Alternative ways of recruiting men need to be explored in future research with older adults in Greek suburban areas. The cross-sectional design precludes asserting causality, yet it affirms links found in longitudinal study designs. Strengths of the present study include the use of robust measures, i.e. triaxial accelerometers for PA assessment and performance-based physical function, as well as a 15-item validated FoF scale in contrast to single-item questions that have been used in existing literature (Bertera & Bertera, 2008; Garbin & Fisher, 2023a).

Significance for exercise science and quality of life

Physical activity guidelines for older adults include at least 150 minutes of moderate-to-vigorous aerobic physical activity (MVPA) per week for benefits in health and well-being. Fear of falling is common among community-dwelling older adults, irrespective of fall history, and can lead to activity restriction in daily living and increased risk of falling, although physical function and other fall risk factors may mediate this relationship. The present study adds to the limited evidence linking fear of falling with device-assessed MVPA, showing that fear of falling is an independent predictor of MVPA in older adults, above and beyond the effects of key confounding factors. Findings suggest that identifying older adults with high fear of falling and addressing these concerns can promote a more active lifestyle in this population.

Acknowledgments

We would like to thank all participants for their time, also the individuals- members of the local settings and researchers- who helped with participant recruitment and data collection, especially Marianna Apostolidou, Ellada Irakleous, Nikos Retzepis and Fani Papanikolaou.

Funding

We acknowledge support of this work by the project "*Study, Design, Development and Implementation of a Holistic System for Upgrading the Quality of Life and Activity of the Elderly*" (MIS 5047294) which is implemented under the Action "*Support for Regional Excellence*", funded by the Operational Programme "*Competitiveness, Entrepreneurship and Innovation*" (NSRF 2014-2020) and co-financed by Greece and the European Union (European Regional Development Fund).

References

Aguilar-Farías, N., Brown, W. J., & Peeters, G. M. (2014). ActiGraph GT3X+ cut-points for identifying sedentary behaviour in older adults in free-living environments. *Journal of Science and Medicine in Sport*, *17*(3), 293-299. https://doi.org/10.1016/j.jsams.2013.07.002

Auais, M., Alvarado, B., Guerra, R., Curcio, C., Freeman, E. E., Ylli, A., Guralnik, J., & Deshpande, N. (2017). Fear of falling and its association with life-space mobility of older adults: a cross-sectional analysis using data from five international sites. *Age and Ageing*, *46*(3), 459-465. https://doi.org/10.1093/ageing/afw239

Bertera, E. M., & Bertera, R. L. (2008). Fear of falling and activity avoidance in a national sample of older adults in the United States. *Health and Social Work*, *33*(1), 54-62. https://doi.org/10.1093/hsw/33.1.54

Billis, E., Strimpakos, N., Kapreli, E., Sakellari, V., Skelton, D. A., Dontas, I., Ioannou, F., Filon, G., & Gioftsos, G. (2011). Cross-cultural validation of the Falls Efficacy Scale International (FES-I) in Greek community-dwelling older adults. *Disability and Rehabilitation*, *33*(19-20), 1776-1784. https://doi.org/10.3109/09638288.2010.546937

Buchner, D. M., Rillamas-Sun, E., Di, C., LaMonte, M. J., Marshall, S. W., Hunt, J., Zhang, Y., Rosenberg, D. E., Lee, I. M., Evenson, K. R., Herring, A. H., Lewis, C. E., Stefanick, M. L., & LaCroix, A. Z. (2017). Accelerometer-Measured Moderate to Vigorous Physical Activity and Incidence Rates of Falls in Older Women. *Journal of the American Geriatrics Society*, *65*(11), 2480-2487. https://doi.org/https://doi.org/10.1111/jgs.14960

Bull, F. C., Al-Ansari, S. S., Biddle, S., Borodulin, K., Buman, M. P., Cardon, G., Carty, C., Chaput, J.-P., Chastin, S., Chou, R., Dempsey, P. C., DiPietro, L., Ekelund, U., Firth, J., Friedenreich, C. M., Garcia, L., Gichu, M., Jago, R., Katzmarzyk, P. T., Lambert, E., Leitzmann, M., Milton, K., Ortega, F. B., Ranasinghe, C., Stamatakis, E., Tiedemann, A., Troiano, R. P., van der Ploeg, H. P., Wari, V., & Willumsen, J. F. (2020). World Health Organization 2020 guidelines on physical activity and sedentary behaviour. *British Journal of Sports Medicine*, *54*(24), 1451–1462. https://doi.org/10.1136/bjsports-2020-102955

Carpenter, M. G., Adkin, A. L., Brawley, L. R., & Frank, J. S. (2006). Postural, physiological and psychological reactions to challenging balance: does age make a difference? *Age and Ageing*, *35*(3), 298-303. https://doi.org/10.1093/ageing/afl002

Choi, K., & Ko, Y. (2015). Characteristics Associated With Fear of Falling and Activity Restriction in South Korean Older Adults. *Journal of Aging and Health*, *27*(6), 1066-1083. https://doi.org/10.1177/0898264315573519

Choi, L., Liu, Z., Matthews, C. E., & Buchowski, M. S. (2011). Validation of accelerometer wear and nonwear time classification algorithm. *Medicine and Science in Sports and Exercise*, *43*(2), 357–364. https://doi.org/10.1249/MSS.0b013e3181ed61a3

de Souza, L. F., Canever, J. B., Moreira, B. S., Danielewicz, A. L., & de Avelar, N. C. P. (2022). Association Between Fear of Falling and Frailty in Community-Dwelling Older Adults: A Systematic Review. *Clinical Interventions in Aging*, *17*, 129-140. https://doi.org/10.2147/cia.S328423

Denkinger, M. D., Lukas, A., Nikolaus, T., & Hauer, K. (2015). Factors associated with fear of falling and associated activity restriction in community-dwelling older adults: a systematic review. *American Journal of Geriatric Psychiatry*, *23*(1), 72-86. https://doi.org/10.1016/j.jagp.2014.03.002

Deshpande, N., Metter, E. J., Lauretani, F., Bandinelli, S., Guralnik, J., & Ferrucci, L. (2008). Activity Restriction Induced by Fear of Falling and Objective and Subjective Measures of Physical Function: A Prospective Cohort Study. *Journal of the American Geriatrics Society*, *56*(4), 615-620. https://doi.org/https://doi.org/10.1111/j.1532-5415.2007.01639.x

Donoghue, O. A., Setti, A., O'Leary, N., & Kenny, R. A. (2017). Self-Reported Unsteadiness Predicts Fear of Falling, Activity Restriction, Falls, and Disability. *Journal of the American Medical Directors Association*, *18*(7), 597-602. https://doi.org/10.1016/j.jamda.2017.01.022

Du, L., Zhang, X., Wang, W., He, Q., Li, T., Chen, S., & Pan, Y. (2022). Associations between objectively measured pattern of physical activity, sedentary behavior and fear of falling in Chinese community-dwelling older women. *Geriatric Nursing*, *46*, 80-85. https://doi.org/https://doi.org/10.1016/j.gerinurse.2022.05.001

Field, A. (2018). *Discovering statistics using SPSS* (4th ed.). Sage.

Fletcher, P. C., Guthrie, D. M., Berg, K., & Hirdes, J. P. (2010). Risk factors for restriction in activity associated with fear of falling among seniors within the community. *Journal of Patient Safety*, *6*(3), 187-191. https://doi.org/10.1097/pts.0b013e3181f1251c

Garbin, A. J., & Fisher, B. E. (2023a). Examining the Role of Physical Function on Future Fall Likelihood in Older Adults With a Fear of Falling, With and Without Activity Restriction. *Journal of Aging and Health*, 8982643231170308. https://doi.org/10.1177/08982643231170308

Garbin, A. J., & Fisher, B. E. (2023b). The Interplay Between Fear of Falling, Balance Performance, and Future Falls: Data From the National Health and Aging Trends Study. *Journal of Geriatric Physical Therapy*, *46*(2), 110-115. https://doi.org/10.1519/jpt.0000000000000324

Gazibara, T., Kurtagic, I., Kisic-Tepavcevic, D., Nurkovic, S., Kovacevic, N., Gazibara, T., & Pekmezovic, T. (2017). Falls, risk factors and fear of falling among persons older than 65 years of age. *Psychogeriatrics*, *17*(4), 215-223. https://doi.org/https://doi.org/10.1111/psyg.12217

Gregg, E. W., Pereira, M. A., & Caspersen, C. J. (2000). Physical Activity, Falls, and Fractures Among Older Adults: A Review of the Epidemiologic Evidence. *Journal of the American Geriatrics Society*, *48*(8), 883-893. https://doi.org/https://doi.org/10.1111/j.1532-5415.2000.tb06884.x

Hadjistavropoulos, T., Delbaere, K., & Fitzgerald, T. D. (2010). Reconceptualizing the Role of Fear of Falling and Balance Confidence in Fall Risk. *Journal of Aging and Health*, *23*(1), 3-23. https://doi.org/10.1177/0898264310378039

Hnizdo, S., Archuleta, R. A., Taylor, B., & Kim, S. C. (2013). Validity and reliability of the modified John Hopkins Fall Risk Assessment Tool for elderly patients in home health care. *Geriatric Nursing*, *34*(5), 423-427. https://doi.org/https://doi.org/10.1016/j.gerinurse.2013.05.011

Howland, J., Lachman, M. E., Peterson, E. W., Cote, J., Kasten, L., & Jette, A. (1998). Covariates of fear of falling and associated activity curtailment. *Gerontologist*, *38*(5), 549-555. https://doi.org/10.1093/geront/38.5.549

Jefferis, B. J., Iliffe, S., Kendrick, D., Kerse, N., Trost, S., Lennon, L. T., Ash, S., Sartini, C., Morris, R. W., Wannamethee, S. G., & Whincup, P. H. (2014). How are falls and fear of falling associated with objectively measured physical activity in a cohort of community-dwelling older men? *BMC Geriatrics*, *14*, 114. https://doi.org/10.1186/1471-2318-14-114

Jefferis, B. J., Merom, D., Sartini, C., Wannamethee, S. G., Ash, S., Lennon, L. T., Iliffe, S., Kendrick, D., & Whincup, P. H. (2015). Physical Activity and Falls in Older Men: The Critical Role of Mobility Limitations. *Medicine and Science in Sports and Exercice*, *47*(10), 2119-2128. https://doi.org/10.1249/mss.0000000000000635

Kendrick, D., Kumar, A., Carpenter, H., Zijlstra, G. A. R., Skelton, D. A., Cook, J. R., Stevens, Z., Belcher, C. M., Haworth, D., Gawler, S. J., & et al. (2014). Exercise for reducing fear of falling in older people living in the community. *Cochrane Database of Systematic Reviews*, 11. https://doi.org/10.1002/14651858.CD009848.pub2

Landers, M. R., Oscar, S., Sasaoka, J., & Vaughn, K. (2016). Balance Confidence and Fear of Falling Avoidance Behavior Are Most Predictive of Falling in Older Adults: Prospective Analysis. *Physical Therapy*, *96*(4), 433-442. https://doi.org/10.2522/ptj.20150184

Lee, L.-L., Arthur, A., & Avis, M. (2008). Using self-efficacy theory to develop interventions that help older people overcome psychological barriers to physical activity: A discussion paper. *International Journal of Nursing Studies*, *45*(11), 1690-1699. https://doi.org/https://doi.org/10.1016/j.ijnurstu.2008.02.012

Lewis, Z. H., Markides, K. S., Ottenbacher, K. J., & Al Snih, S. (2016). The Role of Physical Activity and Physical Function on the Risk of Falls in Older Mexican Americans. *Journal of Aging and Physical Activity*, *24*(3), 342-349. https://doi.org/10.1123/japa.2015-0150

Liu, M., Hou, T., Li, Y., Sun, X., Szanton, S. L., Clemson, L., & Davidson, P. M. (2021). Fear of falling is as important as multiple previous falls in terms of limiting daily activities: a longitudinal study. *BMC Geriatrics*, *21*(1), 350. https://doi.org/10.1186/s12877-021-02305-8

Lusardi, M. M., Fritz, S., Middleton, A., Allison, L., Wingood, M., Phillips, E., Criss, M., Verma, S., Osborne, J., & Chui, K. K. (2017). Determining Risk of Falls in Community Dwelling Older Adults: A Systematic Review and Meta-analysis Using Posttest Probability. *Journal of Geriatric Physical Therapy*, *40*(1), 1-36. https://doi.org/10.1519/jpt.0000000000000099

Mendes da Costa, E., Pepersack, T., Godin, I., Bantuelle, M., Petit, B., & Levêque, A. (2012). Fear of falling and associated activity restriction in older people. results of a cross-sectional study conducted in a Belgian town. *Archives of Public Health*, *70*(1), 1. https://doi.org/10.1186/0778-7367-70-1

Mullen, S. P., McAuley, E., Satariano, W. A., Kealey, M., & Prohaska, T. R. (2012). Physical Activity and Functional Limitations in Older Adults: The Influence of Self-Efficacy and Functional Performance. *The Journals of Gerontology: Series B*, *67B*(3), 354-361. https://doi.org/10.1093/geronb/gbs036

Murphy, S. L., Williams, C. S., & Gill, T. M. (2002). Characteristics associated with fear of falling and activity restriction in community-living older persons. *Journal of the American Geriatrics Society*, *50*(3), 516-520. https://doi.org/10.1046/j.1532-5415.2002.50119.x

NICE. (2013). *Falls in older people: Assessing risk and prevention*. https://www.nice.org.uk/guidance/cg161

Papadimitriou, A., & Perry, M. (2020). Systematic Review of the Effects of Cognitive and Behavioral Interventions on Fall-Related Psychological Concerns in Older Adults. *Journal of Aging and Physical Activity*, *28*(1), 155-168. https://doi.org/10.1123/japa.2017-0408

Park, S.-H., & Kwak, M.-J. (2021). Performance of the Geriatric Depression Scale-15 with Older Adults Aged over 65 Years: An Updated Review 2000-2019. *Clinical Gerontologist*, *44*(2), 83-96. https://doi.org/10.1080/07317115.2020.1839992

Parry, S. W., Bamford, C., Deary, V., Finch, T. L., Gray, J., MacDonald, C., McMeekin, P., Sabin, N. J., Steen, I. N., Whitney, S. L., & McColl, E. M. (2016). Cognitive-behavioural therapy-based intervention to reduce fear of falling in older people: therapy development and randomised controlled trial - the Strategies for Increasing Independence, Confidence and Energy (STRIDE) study. *Health Technology Assessment*, *20*(56), 1-206. https://doi.org/10.3310/hta20560

Ramsey, K. A., Zhou, W., Rojer, A. G. M., Reijnierse, E. M., & Maier, A. B. (2022). Associations of objectively measured physical activity and sedentary behaviour with fall-related outcomes in older adults: A systematic review. *Annals of Physical and Rehabilitation Medicine*, *65*(2), 101571. https://doi.org/https://doi.org/10.1016/j.rehab.2021.101571

Rikli, R. E., & Jones, C. J. (1999). Functional Fitness Normative Scores for Community-Residing Older Adults, Ages 60-94. *Journal of Aging and Physical Activity*, *7*(2), 162-181. https://doi.org/10.1123/japa.7.2.162

Sallis, J. F., & Owen, N. (2015). Ecological models of health behavior. In *Health behavior: theory, reserch and practice* (Revised 4th ed., pp. 43-64). Jossey-Bass, A Wiley Brand.

Santos-Lozano, A., Santín-Medeiros, F., Cardon, G., Torres-Luque, G., Bailón, R., Bergmeir, C., Ruiz, J. R., Lucia, A., & Garatachea, N. (2013). Actigraph GT3X: validation and determination of physical activity intensity cut points. *International Journal of Sports Medicine*, *34*(11), 975-982. https://doi.org/10.1055/s-0033-1337945

Sartor-Glittenberg, C., Bordenave, E., Bay, C., Bordenave, L., & Alexander, J. L. (2018). Effect of a Matter of Balance programme on avoidance behaviour due to fear of falling in older adults. *Psychogeriatrics*, *18*(3), 224-230. https://doi.org/10.1111/psyg.12310

Schoene, D., Heller, C., Aung, Y. N., Sieber, C. C., Kemmler, W., & Freiberger, E. (2019). A systematic review on the influence of fear of falling on quality of life in older people: is there a role for falls? *Clinical Interventions in Aging*, *14*, 701-719. https://doi.org/10.2147/cia.S197857

Stevens, J. A. (2013). The STEADI Tool Kit: A Fall Prevention Resource for Health Care Providers. *IHS Primary Care Provider*, *39*(9), 162-166.

Stubbs, B., West, E., Patchay, S., & Schofield, P. (2014). Is there a relationship between pain and psychological concerns related to falling in community dwelling older adults? A systematic review. *Disability and Rehabilitation*, *36*(23), 1931-1942. https://doi.org/10.3109/09638288.2014.882419

U.S. Department of Health and Human Services, D. (2018). Physical Activity Guidelines for Americans. In (2nd ed.). Washinghton, DC: U.S.

Vitorino, L. M., Marques-Vieira, C., Low, G., Sousa, L., & Cruz, J. P. (2019). Fear of falling among Brazilian and Portuguese older adults. *International Journal of Older People Nursing*, *14*(2), e12230. https://doi.org/10.1111/opn.12230

Vlaeyen, J. W. S., & Linton, S. J. (2000). Fear-avoidance and its consequences in chronic musculoskeletal pain: a state of the art. *PAIN*, *85*(3), 317-332. https://doi.org/https://doi.org/10.1016/S0304-3959(99)00242-0

Wetherell, J. L., Johnson, K., Chang, D., Ward, S. R., Bower, E. S., Merz, C., & Petkus, A. J. (2016). Activity, balance, learning, and exposure (ABLE): a new intervention for fear of falling. *International Journal of Geriatric Psychiatry*, *31*(7), 791-798. https://doi.org/10.1002/gps.4393

Wijlhuizen, G. J., Chorus, A. M. J., & Hopman-Rock, M. (2008). Fragility, fear of falling, physical activity and falls among older persons: Some theoretical considerations to interpret mediation. *Preventive Medicine*, *46*(6), 612-614. https://doi.org/https://doi.org/10.1016/j.ypmed.2008.01.016

Wu, S., Li, G., Shi, B., Ge, H., & He, Q. (2023). The association between physical activity and fear of falling among community-dwelling older women in China: the mediating role of physical fitness. *Frontiers in Public Health*, *11*, 1241668. https://doi.org/10.3389/fpubh.2023.1241668

Yardley, L., Beyer, N., Hauer, K., Kempen, G., Piot-Ziegler, C., & Todd, C. (2005). Development and initial validation of the Falls Efficacy Scale-International (FES-I). *Age and Ageing*, *34*(6), 614-619. https://doi.org/10.1093/ageing/afi196

Yesavage, J. A., & Sheikh, J. I. (1986). 9/Geriatric depression scale (GDS) recent evidence and development of a shorter version. *Clinical Gerontologist*, *5*(1-2), 165-173.