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Objective and self-reported physical activity and risk of falling among community-dwelling older adults from Southern Brazil

Abstract

This study evaluated prospective associations between self-reported and objectively measured physical activity (PA) and risk of falls among older adults. A cohort study started in 2014 with 1,451 community-dwelling older adults living in Pelotas, Brazil. Leisure-time PA was obtained by the International Physical Activity Questionnaire and 7-days raw accelerometer data evaluated for total, light (LPA), and moderate-to-vigorous PA (MVPA). In 2016-7 participants recorded their falls in the previous 12 months. Around 23% of the 1,161 participants followed-up in 2016-7 experienced a fall in the last 12 months. Participants who did not spend any time in self-reported leisure-time PA at baseline had on average 34% higher risk of falls, and individuals in the lowest tertile for MVPA had on average 51% higher risk of falls compared to those in the highest tertile. Low levels of self-reported and objectively measured MVPA were related to higher risk of falling among Brazilian older adults.

Keywords: motor activity; falling; aging; longitudinal studies.

Introduction

The number of older adults in Brazil increased ~40% between 2002 and 2012(Miranda et al., 2016) and the Brazilian Institute of Geography and Statistics (IBGE) estimates that older adults will be around a quarter of the total population in 2060 (Instituto Brasileiro de Geografia e Estatística, 2018). The increase in the senior population is partially responsible for the changes in the morbidity and mortality profile observed in Brazil in the last decades, characterised by an elevated number of cases and deaths by non-communicable chronic diseases (Schmidt et al., 2011).

Non-communicable diseases among older people are also accompanied by functional dependence, polypharmacy, and frailty, that are largely and positively related to the risk of falls (World Health Organization, 2007). Around 28-35% of people older than 65 years fall each year, and it was estimated that 2.6 to 41.4 per 10,000 individuals were admitted to hospitals due to falls in Brazil in 1996 and 2012 (Abreu et al., 2018; World Health Organization, 2007). This is especially concerning given that the World Health Organization estimates that ~646,000 individuals per year die from falls worldwide, of which over 80% are from low- and middle-income countries such as Brazil (World Health Organization, 2007).

One important modifiable behaviour that reduces the risk of falling among older adults is physical activity (PA) (2018 Physical Activity Guidelines Advisory Committee, 2018; World Health Organization, 2007). The literature suggests the implementation of PA as a stand-alone intervention to be the most cost-effective approach for the prevention of falls at population level (Davis et al., 2010). Physical activity may improve strength, balance, and physical fitness, that are negatively related the risk of falls (2018 Physical Activity Guidelines Advisory Committee, 2018).

In fact, there is evidence that structured PA (e.g. exercise) have potential to decrease falls in community-dwelling older people (Sherrington et al., 2017), and a recent systematic review and meta-analysis reported that the risk of recurrent falls is decreased in physically active older adults. However, the relationship between falls (of any type and severity) and free-living PA levels is yet inconclusive (Soares et al., 2018). The systematic review found inconclusive evidence between free-living PA and risk of falls possibly explained by the low number of studies assessing physical activity by device-based methods (e.g. accelerometry). Moreover, all investigations were conducted in the United States or Europe (Soares et al., 2018), which have different macro determinants of healthy ageing than Latin America.

In addition, the intensity of physical activity for fall prevention is unclear. For example, while moderate-to-vigorous PA (MVPA) may be more effective at preventing falls (Buchner et al., 2017; Cauley et al., 2013), older adults generally tend to participate in lower intensity PA (LPA) more often than MVPA (Garatachea et al., 2010). Moreover, results may be different according to the method used to measure PA. Beside relevant differences among several self-reported instruments, studies have reported poor agreement between indirect and direct methods (Kowalski et al., 2012). Thus, this study aims to evaluate the association between self-reported and objectively measured PA of different intensities and the prospective risk of falls among community-dwelling older adults living in the Southern Brazil.

Methods

Participants

This is a prospective cohort study involving ≥ 60 years old adults from the urban area of Pelotas, a medium-sized Brazilian city located at the state Rio Grande do Sul, ~145 kilometers from Uruguay. Baseline data was obtained between January and August

2014 as part of the consort: *Consórcio de Mestrado Orientado para a Valorização da Atenção ao Idoso* "*COMO VAI?*" (HOW ARE YOU?). Household interviews were conducted using standardised interviews, together with anthropometric measurements and physical tests conducted by trained staff. The "*COMO VAI?*" study did not include institutionalized older (i.e. long-term care institution, long hospitalised, etc.), and older subjects incapable of answering to the questions in absence of a caregiver. The current study could not include bed-bound and severely disabled (n=41) old adults for the PA assessment.

A representative sample was obtained from two sampling stages. Initially, 133 census tracts were selected from 469 possibilities, considering the size of census tracts after being sorted by mean income. Thirty-one households were selected in each tract, considering that at least 12 older adults would be identified per tract using a prior estimate of 0.43 older subjects/household. The sampling strategy aimed to identify 1,649 older adults, based on a sample size calculated for all objectives of the study. This sample size also considered losses, refusals and confounders variables.

The first follow-up was performed from November 2016 to April 2017 when confirmation of names and date of birth of the participants were obtained. In addition, health monitoring, and health outcomes such as hospitalizations, morbidities, and functional capacity were asked. This survey was completed by phone, with household visits when phone contact was impossible.

Phone calls were completed by census tracts. After all possible phone calls had been made for all the participants in a census tract, a list with study identification number, name, date of interview in 2014, address, and city map was obtained to the household visits. Every Monday a list containing the addresses to be visited during the week was given to the interviewers (nutrition students trained prior to interviews). Participants were visited at their households at least twice per week at different days and hours. Each address was visited during the fieldwork at least in two random weeks. In case of address changes and no possible phone contact, participants were traced in their new location if still living in Pelotas. Interviews were performed with the participants with the possibility of help from the caregiver when they are not able to answer to the questions accurately. Interviews were done using the Research Eletronic Data Capture – REDCap (https://projectredcap.org/).

Deaths were reported at phone calls or households by a relative or nearest neighbour and confirmed by consulting the Mortality Information System (SIM). The confirmation was done with the permission of the Department of Epidemiologic Surveillance of Municipal Health Secretary of Pelotas. We recorded deaths occurring up to April 30, 2017.

All phases of the study were approved by the Research Ethics Committee of the School of Medicine of the xxxxxxxxxxx. Informed consent was obtained from all participants or their caregivers prior to the interviews at baseline and follow-up.

Physical activity

Physical activity was assessed during the household interview in 2014. Objectively measured PA was assessed using GENEActiv® accelerometers (Activinsights Ltd, Kimbolton, Cambs, UK, http://www.geneactiv.org). The GENEActiv® accelerometer is a waterproof device which measures acceleration in three axes at 85.7 Hz and provides raw data expressed in gravitational equivalent units (1000mg=1g). Participants were asked to wear the accelerometer on their non-dominant wrist for 24 hours for seven days following the interview, including during water-based activities.

The research team was responsible for fitting and collecting the devices at the participant's home as previously described elsewhere (Ramires et al., 2017).

The accelerometers data were downloaded with the GENEActiv software and analysed using the R-package GGRI v1.1-5 (https://cran.r-project.org/web/packages/GGIR/vignettes/GGIR.html#citing-ggir). Raw data were calibrated to local gravity (van Hees et al., 2014), and inspected for non-wear time defined as periods greater than 60 minutes of low acceleration variability (SD <13 m*g*). Abnormally high values were removed, and invalid data segments imputed (within individual) using the averaged data points from similar time of the day from other valid days of measurements. Participants with less than two days of valid data were excluded from the analyses. Activity-related acceleration was calculated using the Euclidian Norm (vector magnitude of the three axes) minus 1 *g* (ENMO = $\sqrt{(x^2 + y^2 + z^2)} - 1\ g$) (van Hees et al., 2013).

Average acceleration (m*g*) across the monitoring period was used as the measure of overall PA, i.e. total volume of movement. The activity intensity distribution was estimated from 5-s aggregated time-series (epoch) as: time spent in light LPA (min/day) calculated as daily time in acceleration between 50 and 99 m*g*; and time spent in MVPA (min/day) calculated as daily time in acceleration higher than 100 m*g* (Hildebrand et al., 2014; White et al., 2016, 2019). For time spent in MVPA, participants should have spent at least four consecutive minutes of a five-minute bouts in activities >100 m*g* of acceleration.

In addition to the objectively measured PA, weekly time spent in leisure-time PA was estimated using the International Physical Activity Questionnaire (IPAQ) – long version (Craig et al., 2003). This questionnaire includes only activities performed for at least 10 consecutive minutes. Participants were classified as 'no' in the leisure-time PA if they reported 0 minutes/week in the IPAQ. Such classification avoided memory bias in the self-reported time spent in LTPA. In addition, statistical power was not enough to show additional categories in this variable since time spent in LTPA was low among our sample.

Falls

Falls in 2014 (baseline) and in 2016-7 (follow-up) were recorded by the question: "Have you fallen down from <month in the previous year> to today?" (yes/no question). We defined falls as "inadvertently coming to rest on the ground, floor or other lower level, excluding intentional change in position to rest in furniture, floor or other objects". Severely disabled individuals in this condition longer than period between baseline and follow-up interviews did not answer such question.

Confounders

The following sociodemographic variables were assessed in the baseline household interview: sex (men, women); age (60-69, 70-79, ≥ 80 years); schooling (none, <8, ≥ 8 complete years of study); economic status (classified as A/B - highest, C, D/E - lowest) evaluated by criteria based on a score described by the *Associação Brasileira de Empresas de Pesquisa* (Associação Brasileira de Empresas de Pesquisa, 2013), which considered the possession of consumer goods, head of household schooling, and the presence of a maid; marital status (married or living with partner, single/divorced, widowed); and smoking status (never, previous smoker, current smoker).

The use of medicines potentially related to the occurrence of falls was evaluated for the 15 days prior to the interview. The drugs considered were psychoactive, pyknoleptic, antiepileptics, calcium channel blockers, diuretics, muscle relaxants, and digoxin. Respondents were asked to show the packaging or prescription of the medicines used. Medicines were classified according to the ATC classification (Anatomical Therapeutic Chemical Classification System) (World Health Organization, 2000).

Self-reported morbidities (yes/no) were obtained by the questionnaire which included: high blood pressure, diabetes, heart diseases, heart failure, lung diseases (asthma, bronchitis or emphysema), arthritis, Parkinson's disease, kidney failure, hypercholesterolemia, seizures, stomach ulcer, osteoporosis, urinary incontinence, constipation, faecal incontinence, depression, glaucoma, deafness, difficulty swallowing, insomnia, fainting, rhinitis, speaking disorders, stroke, mental disorders and cancer.

Weight was measured at home using a digital scale (Tanita UM-080, Tanita, Tokyo, Japan) and knee height was measured with a portable paediatric wooden stadiometer to estimate their standing height using equations suggested by Chumlea (Chumlea & Guo, 1992). Body mass index (BMI) was calculated as weight (kg) divided by height (m) squared (World Health Organization, 1995), from which obesity was classified according to WHO criterion of ≥ 30 kg/m^2.

Statistical analyses

Absolute and relative frequencies of participants' characteristics at baseline were described for the whole sample and also for those who participated in the follow-up (based on eligible participants), as well as the frequency of individuals who fell in the last year prior to the follow-up interview. Crude association between falls in the last year prior to the follow-up interview and participants' characteristics at baseline were tested by the Pearson's Qui-squared test. Overall PA, LPA and MVPA (min/day) are presented as mean and standard deviation and participants were grouped into tertiles. Frequency of participants who fell in the last year prior to the follow-up interview was described according to self-reported PA (yes/no) and classified as none, 1, 2, 3, ≥ 4 according to the number of falls.

Poisson regressions were conducted for the bivariate and multivariate analyses (relative risk – RR – were provided). The most active participants for PA measures were used as the reference group for estimating the risk of falling and respective 95% confidence intervals. Analyses were conducted in two models: 1) adjustment for sex, age, skin colour, schooling, and smoking status; and 2) model 1 further adjusted for the use of medicines, number of diseases and falls at baseline. In these models all covariates with $p<0.20$ were kept in the final analysis. Significance level was set at 5% and all statistical analyses were performed with Stata 13.0 software (StataCorp, College Station, TX, USA).

Results

From 1,844 older individuals located in 2014, 1,451 were recruited into the study for baseline measures (78.7%). Self-reported and objectively measured PA was available in 1,391 (95.9%) and 971 participants (66.9%), respectively. A total of 1,161 were interviewed in 2016-7 (follow-up rate: 89.5%, including 145 known deaths up to April 30, 2017) and 1,140 of them provided information about falls (Figure 1). Individuals were followed up on average by 2.6 years.

Table 1 describes baseline characteristics of the whole sample in 2014, and those followed-up (deaths were included as traced) in 2016-7. In general, sample characteristics at baseline were maintained at follow-up. Most of the interviewed were women (~63%), aged between 60 and 68 at baseline (52.3% of the original sample and

56.0% of the followed participants), studied less than 8 years (~54%). Majority of the participants were classified in the socio-economic status C (~53%), were married (52.7% of the original sample and 55.9% of the followed participants) and never smoker (54% of the original sample and 56% of the followed participants). Seven or more diseases were most prevalent, and 61% used medicines potentially related to the occurrence of falls. Around 72% had not fallen in the last year prior to the baseline interview. Overall PA was 22.4 mg (SD=8.1 mg) and daily time spent in LPA and MVPA was 137.5 minutes (SD=56.6 minutes) and 11.6 minutes (SD=17.4 minutes), respectively. Moreover, around 31% of the participants did not practice any leisure-time PA. Of all possible confounders examined, only economic status was not statistically associated with frequency of falls (p=0.431). (Table 1)

Frequency of individuals who reported any falls were 27.1% and 23.4% in 2014 and 2016-7, respectively. At follow-up (2016-7), the percentage of individuals who reported falls was 22.6% by phone and 25.9% by face-to-face interviews (p=0.258). Around 13% of the followed participants reported falling once and 5% falling twice (Figure 2).

Table 2 shows higher unadjusted occurrence of falls among older adults who did not report any leisure-time PA and among those classified in first (lowest) tertile of overall PA, LPA and MVPA (p<0.05 in all analyses). The risk of falling was not statistically significant for overall PA in multivariate analyses adjusted for SES and smoking (p=0.119). Individuals classified in the lowest tertile of MVPA had on average 65% higher occurrence of falls at follow-up (95%CI: 1.16; 2.35; p=0.019) following adjustment for these covariates.

After adjustment for the use of medicines, number of diseases, and falls at baseline (Figure 3), participants who reported doing no leisure-time PA at baseline had on average 34% higher risk of falls (95%CI: 1.03; 1.76). At this level of adjustment, there was a non-significant 28% (95%CI: 0.93; 1.77) and 30% (95%CI: 0.95; 1.77) higher risk of falling at follow-up among participants in the least active compared to the most active for device-measured overall PA and LPA. Individuals in the lowest tertile of MVPA had on average 51% higher risk of falls compared to the most active (95%CI: 1.06; 2.16).

Discussion

The main findings of the current study were that leisure-time PA and objectively measured moderate-to-vigorous PA were negatively associated with the risk of falling. On the contrary, associations with objectively measured overall PA and light PA did not reach statistical significance. To the best of our knowledge this is the first study that evaluated the association of free-living PA measured by accelerometers and risk of falling among older adults using a prospective approach in a middle-income country.

Although a previous meta-analysis reported that structured exercise programs were more effective for falling prevention when the exercise did not include walking (Sherrington et al., 2017; Voukelatos et al., 2015), our objective measure of MVPA included all kind of activities, including walking. However, there are scarce prospective results from free-living MVPA. Thus, supervised exercise trials provided the majority of the evidence on MVPA and falls in older individuals (Buchner et al., 2017). This reflects in the *2018 United States Physical Activity Scientific Report* which states that participation in multicomponent group, home-based fall prevention PA, and exercise programs by community-dwelling older adults can significantly reduce the risk of falls and falls-related injuries.

In fact, there is only limited evidence that a dose-response relationship exists between the amount of free-living MVPA and risk of falls (2018 Physical Activity Guidelines Advisory Committee, 2018), and our study further adds to the literature by showing a linear decrease in the risk of falling across MVPA tertiles. For example, in the present representative sample, a ~7 minutes difference in daily MVPA was associated with a 25% lower risk of falls and a further difference in MVPA of about 36 minutes was associated with a 51% lower rate of falls. These results are promising because achieving these MVPA levels per day may be feasible for many of those in this population.

Despite the lower risk of falls associated with a longer time in MVPA observed in the present study, PA may also increase the risk of falls. For instance, older adults performing >4 hours of planned PA per week were at higher risk of falls (Delbaere et al., 2010). In addition, higher risk of falls has also been reported in older adults with low levels of PA. For example, findings from the Activity and Function in the Elderly in Ulm study reported that average daily walking duration assessed by thigh-worn uni-axial accelerometers was not associated with risk of falling during a 12-months follow-up; however those who were low active (walked less than one hour per day) had significantly more falls per hours walked compared to high active individuals (Klenk et al., 2015). Walking may be recommended when older adults have the strength, balance, and cognition necessary to perform it safely and within their limitations (Bauman et al., 2016), although there is insufficient evidence to determine whether the strength, balance, and cognition can modify the associations between PA and falls (2018 Physical Activity Guidelines Advisory Committee, 2018). In the current study, after adjusting for previous falls, the negative association between MVPA and falls remained significant. Different methods in the assessment of physical activity and in the adjustment for potential confounders, as well as the age range of the studied sample may explain such divergent findings.

Similarly to the objectively measured MVPA, results from studies based on self-reported measurements have also shown positive results from PA in avoiding falls in the older population (Soares et al., 2018). The literature indicates appropriate PA may modify primary determinants for falls, including osteopenia, poor balance, and muscle weakness (American College of Sports Medicine, 2009).

In the present investigation, accelerometer was used to objectively measure MVPA of the elderly. Acceleration was used to obtain a free of recall-bias assessment of physical activity among the elderly (Kowalski et al., 2012). Furthermore, a recent study has demonstrated excellent criteria-validity for an acceleration of 98 mg to classify MVPA (Fraysse et al., 2021) against indirect calorimetry (sensitivity of 0.90 and specificity of 0.79). A cut-off of 98 mg is comparable to the one adopted in our present investigation (>100 mg), and is also similar to others (Hildebrand et al., 2014; Sanders et al., 2019). Finally, because accelerometers provide no information about the domain of the activity being performed, in the present study we also used questionnaires to measure leisure time physical activity.

The main strength of our study is the use of accelerometers to measure PA. Although findings from associations of self-reported leisure-time PA and objectively measured PA with the risk of falls were consistent – despite several losses of the equipment, self-reported PA is susceptible to bias, less likely to assess LPA and total PA accurately and do not provide exact amount of time spent in different intensity levels (Kowalski et al., 2012). Even our PA information is based on wrist measures, as previous study reported excellent validity of our cut-offs also for PA measured in the non-dominant wrist (Fraysse et al., 2021) and the use of accelerometers on this body location has the best wear compliance and the additional benefit of allowing the measurement of movement during sleep (Doherty et al., 2017; Troiano et al., 2014), our objective method to assess PA is an important strength of the current study. On the other hand, results from self-reported leisure-time PA cannot be neglected, since public polices to promote PA in this age group have higher potential to increase PA in the leisure-time than change PA levels in the household or work environments, for example. In addition, despite self-reported PA is more susceptible to biased estimates, information regarding time spent in PA in specific domains is only possible in large samples using self-reported instruments, thus, future studies should investigate and propose valid questionnaires driving their attention especially to household domain and light physical activity, since time spent in leisure-time PA is low among older adults (75% of our sample spent less than 75 minutes/week in leisure-time PA). Moreover, our study allowed the presence of a caregiver with the older person during the interview to help in the recall, and the categories used in the analyses (any versus no LTPA) is less vulnerable to bias since specific time spent was not considered.

The study of a representative sample of community-dwelling older individuals with a high response rate and follow-up rate is another strength of the present investigation. In addition, we aimed to reduce the risk for confounding by adjustment for previous falls in our analyses, as well as other comorbidities and use of specific medicines potentially related to the risk of falls. However, we cannot rule out that unmeasured confounding may have affected our results.

One important limitation is the small sample size of the objectively measured PA. On the contrary, this is probably the first study using raw accelerometer data in a population-based sample of Brazilian older adults and the analytical sample is likely representative of the city of Pelotas, as the missingness was randomly distributed. Some loss to follow-up was observed which was due to errors in names, addresses and phone numbers of the participants, since this cohort study was not initially designed to be a longitudinal investigation. Moreover, due to funding and logistics we were not able to perform all interviews face-to-face and some bias may be present for phone-based data collection, although there was no statistically significant difference in frequency of falls between methods of interview.

In summary, findings from this cohort study in Southern Brazilian older adults showed a higher risk of falling in individuals with lower levels of MVPA, based on self-report and accelerometry. In spite of non-statistically significant results for LPA, the point estimates suggesting a beneficial association between LPA and falls should not be discarded. The growing importance of LPA to a healthy aging process is relevant to the maintenance of its promotion, even though some higher intensity may be required for better prevention of falls. The growing number of older people in general population in the upcoming decades and the considerable hazardous effect that falls could produce in these individuals, treating their health and even causing risk of deaths, reinforce the importance of this study and the need to stimulate PA for this population in order to improve their quality of life. Public policies designing PA interventions, especially focused for the leisure-time and moderate-to-vigorous intensity PA, for aged adults would be highly recommended.

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