Qual Life Res (2017) 26:25–34
DOI 10.1007/s11136-016-1374-7

Age- and gender-specific associations between insomnia and falls in Boston Puerto Rican adults

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Accepted: 18 July 2016 / Published online: 23 July 2016
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Abstract
Purpose This study evaluated the age- and gender-specific associations between insomnia and falls in community-dwelling Puerto Rican adults, independently of multiple covariates.
Methods Cross-sectional data were collected from 954 Puerto Ricans, aged 46–79 years, in Boston, Massachusetts. In-person interviews were conducted to collect information on sociodemographics and lifestyle, mental status, medication use, comorbidities, sleep duration, insomnia symptoms, and falls and fractures. Blood and urine samples, and bone density measures were collected to assess C-reactive protein, serum interleukin-6, urinary cortisol, and bone mineral density.
Results Multivariate robust Poisson regressions suggested that adults with insomnia had a 32 % increased likelihood of having falls (PR 1.32, $p < 0.05$), after adjustment for multiple covariates. Age and gender modified the effect of insomnia on risk of falls. Insomnia was significantly associated with higher risk of falls in adults of 60 years or older (PR 1.49, $p < 0.05$) and in women (PR 1.36, $p < 0.05$), but not in adults younger than 60 years or in men. Insomnia was not associated with recurrent falls or fractures.
Conclusions Age and gender need to be taken into account when considering treatment of insomnia in preventing geriatric falls. Well-designed evidence-based interventions to treat insomnia and improve sleep quality may reduce the risk of falls in this population.

Keywords Accidental falls · Recurrent falls · Sleep disorders · Hispanics · Sleep medication

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Introduction

The incidence of falls is notably high among the elderly population, with an estimated one-third of those aged 65 years or older falling every year [1]. The prevalence of falls in this age group in the USA increased by 8 % over the past decade [2]. Falls in older adults contribute to morbidity and mortality [3], loss of independence, emergency visits and hospitalizations [4], and early admission to long-term care facilities [5]. The estimated annual direct medical cost of falls is expected to reach $32 billion by 2020 [6]. Although the burden of falls is well documented in the elderly population, research suggests that falls and

negative consequences are also common among middle-aged adults [7].

Insomnia is prevalent in the elderly population. From a sample of about 6000 community-dwelling older adults, more than 70 % reported at least one insomnia symptom [8]. Another study reported that the prevalence of insomnia was almost 40 % in middle-aged and older adults [9]. Individuals who experienced insomnia symptoms were more likely to have poor postural control [10], poor vigilance [11], as well as poor attention and slow reaction time [12], which may increase the risk of falls.

Sleep has been linked to falls in the elderly population. The risk of falls has been shown to be higher among older adults with shorter or longer sleep duration [13–16], excessive daytime sleepiness [17], or sleep disturbances [13, 18]. The association between sleep and falls may vary by gender. Kuo et al. [14] and Mesas et al. [15] reported that this association between sleep duration and falls was more prominent in women than in men. However, the association between sleep and falls has rarely been studied in middle-aged adults. In addition, few large studies have examined the association between insomnia and falls in community-dwelling adults, particularly by age and gender. Inadequate collection of covariate information such as medication use and comorbidities has also limited existing studies.

Insomnia may be associated with medical and psychiatric comorbidities. Previous studies reported associations of insomnia with use of insomnia medication [8], depression [8], and impaired cognitive function in elders [19, 20]. Vieira et al. [21] reported that, in addition to sleep disturbances, confusion and cognitive impairment were among the most significant risk factors for geriatric patient falls. About 20 % of community-dwelling elders used psychotropic medications, including antipsychotics, antidepressants, and antianxiety agents [22]. Psychotropic medications have been identified as an important independent risk factor for falls [23, 24]. Tinetti et al. [25] reported that sedative use was a much stronger predictor of falls in the elderly than cognitive impairment, disability of lower extremities, or abnormalities of balance and gait. Whether the association between insomnia and falls is independent of medication use and comorbidities is still unclear and warrants further attention.

Most of the research on sleep and falls has been performed in non-Hispanic whites, limiting generalization. The prevalence and incidence of chronic conditions may differ by racial and ethnic group. Community-dwelling Puerto Rican adults living in Massachusetts (MA) reported high prevalence of obesity, type 2 diabetes, hypertension, arthritis, and depression [26]. The objectives of this study were to evaluate whether insomnia was associated with falls among community-dwelling Puerto Rican adults living in Boston, MA, independently of medication use, mental status, comorbidities, and other covariates, and to test for effect modification by age and gender.

Methods

Study design and data collection

This analysis used cross-sectional data from the Boston Puerto Rican Health Study (BPRHS) and the Boston Puerto Rican Osteoporosis Study (BPROS). The BPRHS is a longitudinal cohort study of Puerto Rican adults, aged 45–75 years at baseline, living in Boston, MA. After baseline (2005–2009) and 2-year follow-up data collection, participants were invited to participate in the BPROS study. We used the cross-sectional data collected from BPRHS 2-year follow-up and BPROS.

At the BPRHS 2-year follow-up, bilingual interviewers administered questionnaires in-person to collect information on sociodemographic and lifestyle factors, mental status, comorbidities, and medication use. Biological samples, including 12-h urine and fasting blood, were collected by the study phlebotomist on the day after the interview.

For the BPROS, participants visited the Metabolic Research Unit at Tufts University to undergo bone density measures and to complete another questionnaire containing information on insomnia symptoms, sleep duration, past fracture history, and number of falls and fractures in the past year. Most of these visits occurred within 1 month of the 2-year follow-up. A total of 958 out of 1261 participants (76 %) who completed the 2-year follow-up consented to the BPROS. Primary reasons for nonparticipation included not being interested, scheduling problems, loss to follow-up, relocation out of Massachusetts, and death. We further excluded 4 participants without complete data on falls, leaving 954 participants in the current analysis.

Individuals who declined to participate in the BPROS were more likely to be older (60.9 years compared to 59.4 years, $p < 0.01$), to be smokers (54.0 % compared to 20.8 %, $p < 0.01$), to have lower BMI (30.3 kg/m^2 compared to 32.2 kg/m^2, $p < 0.01$), and to have fewer depressive symptoms (Center for Epidemiologic Studies Depression Scale (CES-D), 16.9 compared to 18.6, $p < 0.05$), relative to participants. No significant differences in gender distribution, alcohol consumption, physical activity, or scores on the Mini-Mental State Examination (MMSE) or Perceived Stress Scale (PSS) were seen.

Measurement of variables

Outcome assessment

Falls were measured with three items in the BPROS study: "During the past year, did you accidentally fall to the ground? (Choose 'No' if the accident occurred during a sports activity)" "If Yes, how many times did you suffer a fall during the last year?" and "Did any of your falls during the last year result in fracture?"

Exposure assessment

Insomnia symptoms were collected with the following questions "How frequently do you have difficulty falling asleep?" "How frequently do you have trouble with waking up at night?" "How frequently do you have trouble with waking up too early in the morning and not being able to fall asleep again?" and "How frequently do you feel truly tired when you wake up in the morning?" Three categories were used to describe the answers: "most of the time," "sometimes," and "almost never or never." Insomnia symptoms were defined as having the symptoms most of the time versus sometimes or never. Participants who reported most of the time for having difficulty initiating sleep, difficulty maintaining sleep, or early-morning awakenings, accompanied with most of the time for non-restorative sleep, were considered to have insomnia disorder [27].

Covariate assessment

Survey measures At the BPRHS 2-year follow-up, information was collected on participants' age, gender, height and weight, drinking and smoking status, and physical activity. BMI was calculated from self-reported weight and height, expressed as weight (Kg)/height $(m)^2$. Participants were categorized as never or former drinker (no drinks within past year), compared to current moderate ($\leq$1 drink daily for women or $\leq$2 drinks daily for men) or heavy drinker (>moderate daily drinking, or binge drinking, defined as >6 drinks during one day of drinking). Smoking status was categorized as never (<100 cigarettes in entire life) or former, compared to current smoker. Physical activity was assessed with a modified Paffenbarger [28] questionnaire from the Harvard Alumni Activity Survey. At the BPROS, information was collected on participants' bone fracture history (yes or no) and hip fracture history (yes or no).

Depressive symptoms were measured with the CES-D (range 0–60), which has been widely used in epidemiologic studies, with good reliability and validity in older adults [29]. Cognitive function was measured with the MMSE (range 0–30), widely used in older adults with good reliability and validity [30]. Stress was measured with the PSS (range 0–56), which also shows good reliability and validity in older adults [31].

Comorbidities were assessed at the BPRHS 2-year follow-up, including questions about previous diagnoses of the following chronic conditions: diabetes, hypertension, arthritis, osteoporosis, cardiovascular diseases, stroke, respiratory diseases, liver/gallbladder diseases, kidney diseases, gastrointestinal diseases, cancers, eye diseases, Parkinson's diseases, and seizures. Self-reported ability to perform 12 Activity of Daily Living (ADL) tasks [32] and 6 Instrumental Activity of Daily Living (IADL) tasks [33] were assessed. ADL (range 0–36) was dichotomized as none or some impairment ($\leq$5), compared to considerable impairment ($\geq$6). IADL (range 0–18) was dichotomized as none or some impairment ($\leq$6), compared to considerable impairment ($\geq$7).

Sleep duration was assessed at the BPROS with a single item "Please include the total number of hours that you really sleep, typically, during a 24 h period." We used one item to assess daytime sleepiness "How frequently do you feel so sleepy during the day or night that you need to take a nap?" and one item to assess snoring "Do you snore? (if you have a partner or share your bedroom with another person, please ask him/her)." Medication use, assessed at the BPRHS 2-year follow-up, included information on the use of antidepressants, antipsychotics, antianxiety agents, and antihistamines.

Serum and urine measures Fasting blood samples (12 h) were drawn from participants by a certified phlebotomist. High-sensitivity C-reactive protein (CRP), indicating the level of inflammation in the body, was measured using a solid-phase, enzyme-labeled chemiluminescent immunometric assay (Immulite 1000, Diagnostic Products Corporation (DCP) Los Angeles, CA 90045-5597) as specified by the manufacturer's procedural documentation (PILKCR-7, 2003-11-25). Serum interleukin-6 (IL-6) concentration, another inflammatory indicator, was measured with a non-cross-reacting enzyme-linked immunoassay (ELISA), employing specific monoclonal and polyclonal antibodies for the analysis of specific cytokine antigens (Quantikine ELISA, R&D Systems, Minneapolis, MN, USA). Urinary cortisol, released in response to physical or emotional stress, was analyzed by direct immunoenzymatic colorimetric method with an ALPCO cortisol assay (ALPCO, Windham, NH), which is standardized by multiplying each measure by total urine volume and dividing by urinary creatinine excretion.

Bone density measures Bone mineral density (g/cm^2), indicating the amount of bone mineral in bone tissue, was measured at the femur by DXA (Lunar model Prodigy scanner; General Electric) using standard procedures. The root-mean-square precision of these measures was 0.65 %

for the femur [34]. During the study, the stability of DXA measurements was determined by scanning an external standard (aluminum spine phantom; Lunar Radiation Corp) every week.

Data analysis

All analyses were conducted using SPSS software 22.0 (IBM Corp., Armonk, NY). Cross-tabulation with Chi-square test and independent samples t tests was utilized to examine relationships between falls (yes versus no) and insomnia. Poisson regression with robust variance estimation was used to calculate prevalence ratios among groups and to investigate potential confounding [35]. This method was selected because the prevalence of falls in the study participants is 31.8 %; therefore, the odds ratio reported in logistic regressions may significantly overestimate the prevalence ratio [35]. Three dependent variables were examined: any accidental fall in the past year (yes vs no); recurrent falls (≥2 falls vs <2 falls); and falls resulting in fracture (yes vs no).

Six sequential Poisson regression models with robust variance estimation were built with adjustment for potential covariates. Model 1 was adjusted for age and gender. Model 2 was further adjusted for other sociodemographic and lifestyle factors. Model 3 was further adjusted for mental status and medication use. Model 4 was further adjusted for comorbidities. Model 5 was further adjusted for biological measures. Model 6 was further adjusted for other sleep variables. Interactions between insomnia and age and gender were tested and, when significant, stratified results were examined for the age- or gender-specific differences in this association. The median age of the study sample (60 years) was used as the cutoff in the stratified analysis. Prevalence ratios and 95 % confidence intervals (CI) were reported at $p < 0.05$ level.

Results

This study included 954 Puerto Rican adults (71.4 % women) with a mean (±SD) age of 59.4 (±7.6) years. A total of 303 (31.8 %) participants reported a fall in the past year; of these, 143 (47.2 %) had recurrent (≥2) falls, and 39 (12.9 %) suffered a fracture. Compared with those who did not fall, those with falls tended to be older, women, obese, and to have had previous fracture (Tables 1, 2). They also reported more depressive symptoms, more chronic diseases, more limitations with ADL and IADL, more use of antidepressants and antianxiety agents, and were more likely to be sleeping ≤6 h per day, to experience difficulty falling asleep, in maintaining sleep, and waking up too early in the morning (Tables 1, 2).

A total of 657 (68.9 %) participants reported at least one insomnia symptom; 380 (39.8 %) reported having difficulty falling asleep; 350 (36.7 %) reported having trouble maintaining sleep; 379 (39.7 %) reported having trouble with waking up too early; and 209 (21.9 %) reported feeling truly tired when waking up. A total of 148 (15.5 %) were classified as having insomnia disorder.

Participants aged 60 years and older reported fewer insomnia disorders (Chi-square = 13.1, $p < 0.01$) but more falls in the past year (Chi-square = 4.72, $p < 0.05$) than those younger than 60 years. Women reported more falls in the past year than men (Chi-square = 14.5, $p < 0.01$). No difference in the prevalence of insomnia disorders was reported between women and men (Chi-square = 1.65, $p > 0.05$) (Table 3).

Insomnia was associated with 33 % greater risk of falls (Table 4, Model 3, PR = 1.33, $p < 0.05$), after adjusting for sociodemographic and lifestyle factors, mental status, and medication use. After additional adjustment for comorbidities, the association between insomnia and falls was attenuated. However, with additional adjustment for biological measures and other sleep variables, the association was retained (Table 4, Model 6, PR 1.32, $p < 0.05$). Medication use was not associated with falls. Insomnia was not associated with either recurrent falls or fractures in the regression models (Table 4).

Interactions were significant between insomnia, age (<60 vs ≥60 years) (PR 1.93, $p < 0.01$), and gender (PR 1.93, $p < 0.01$), after adjusting for sociodemographic and lifestyle factors, mental status, and medication use, in relation to falls. We, therefore, stratified the sample to test the age- and gender-specific differences in the association. Insomnia was associated with 49 % greater risk of falls in adults 60 years or older (Table 5, Model 3, PR 1.49, $p < 0.05$), but not in those younger than 60 years; women with insomnia had 36 % greater risk of falls than those without insomnia (Table 5, Model 3, PR 1.36, $p < 0.05$), while men did not, after adjusting for sociodemographic and lifestyle factors, mental status, and medication use. After additional adjustment for comorbidities, the association between insomnia and falls was attenuated in both older adults (≥60 years) and women. With further adjustment for biological measures and other sleep variables, the association in women regained significance (Table 5, Model 6, PR 1.37, $p < 0.05$).

Discussion

This study suggests that insomnia was significantly associated with falls in Boston Puerto Rican adults aged 60 years or older (60–79 years), but not in adults younger than 60 years (46–59 years) and in women (46–79 years),

Table 1 Sociodemographics, lifestyle, mental status, and biological measures of Puerto Rican adults, by falls in the past year ($n = 954$)

Characteristics (continuous variables)	All participants ($n = 954$) (Mean ± SD)	No falls in the past year ($n = 651$) (Mean ± SD)	Falls in the past year ($n = 303$) (Mean ± SD)
Sociodemograhpic and lifestyle			
Age	59.4 ± 7.6	59.0 ± 7.5*	60.2 ± 7.9*
BMI	32.1 ± 6.6	31.9 ± 6.5*	32.8 ± 6.7*
Physical activity	31.8 ± 4.6	31.9 ± 4.8	31.5 ± 4.2
Mental status			
Depressive symptoms (CES-D)	18.6 ± 12.6	17.8 ± 12.7**	20.1 ± 12.3**
Cognitive impairments (MMSE)	23.3 ± 3.3	23.5 ± 3.3*	23.0 ± 3.4*
Stress (PSS)	23.1 ± 8.9	22.8 ± 8.9**	24.9 ± 8.2**
Biological measures			
CRP	6.7 ± 11.8	6.5 ± 9.6	7.1 ± 15.6
IL-6	4.0 ± 4.2	4.0 ± 4.2	4.2 ± 4.0
Urinary Cortisol	38.8 ± 31.9	38.3 ± 31.9	39.9 ± 31.8
BMD femur	1.03 ± 0.16	1.04 ± 0.17*	1.01 ± 0.16*

Independent samples *t* test was used to compare the mean differences of variables between the two groups

SD standard deviation, *BMI* body mass index, *CES-D* Center for Epidemiologic Studies Depression Scale (range 0–60), *MMSE* Mini-Mental State Examination (range 0–30), *PSS* Perceived Stress Scale (range 0–56); *CRP* C-reactive protein, *IL-6* interleukin 6, *BMD* bone mineral density

[a] $p < 0.10$; * $p < 0.05$; ** $p < 0.01$

but not in men (46–79 years), independently of sociodemographic and lifestyle factors, mental status, and medication use. Insomnia was not associated with recurrent, relative to single, falls or with fractures. While previous studies have assessed sleep and falls in non-Hispanic white elders, this is the first study, to our knowledge, to examine the association between insomnia and falls in a large sample of middle-aged and older Puerto Rican adults. Little sleep research has been done in the US Hispanic population [36]. Due to major health disparities, including higher prevalences of obesity, diabetes, substance abuse, and others, Hispanics may be more likely than non-Hispanic whites to suffer sleep disorders [36]. Better understanding of the association between insomnia and falls is, therefore, of great importance in this population.

Our study results are consistent with the previous findings, reported in elderly groups, that insomnia is a risk factor for falls. In a cross-sectional study with 34,163 nursing home residents, Avidan et al. [37] reported that insomnia predicted subsequent falls, with untreated insomnia and hypnotic-treated (unresponsive) insomnia predicting more falls than did the absence of insomnia. Stone et al. [38] reported that subjectively and objectively measured sleep problems were associated with increased risk of falls, independent from the use of insomnia medication, in community-dwelling older women. In contrast to Tinetti [25], but consistent with Avidan and Stone [37, 38], we did not find an association between medication use and falls after adjustment for covariates. Although medication use may impair posture, reaction time, and coordination, these effects may be attributable to other health conditions of medication users, such as medical or psychological comorbidities. Whether effective treatment of insomnia with medication in the elderly will help prevent falls remains controversial [37, 38]. A meta-analysis of risks and benefits for use of sedative hypnotics suggested a small effect on sleep improvement, but increased risk of cognitive events, psychomotor events, and daytime fatigue [39]. In this study, we did not find an association between insomnia and recurrent falls and fracture. Avidan et al. [37] reported an association of both insomnia and hypnotics use with hip fracture, but these associations disappeared after adjustment for covariates. Previous studies have suggested that short or long sleep duration rather than sleep disturbances could be risk factors for fracture in the elderly [16].

In our study, the association between insomnia and falls did not remain significant after adjusting for multiple comorbidities. A possible explanation is that insomnia may be secondary to one or more primary health conditions. However, after further adjustment for biological measures, including CRP, IL-6, urinary cortisol, and bone mineral density, the association was again significant, suggesting that there might be some negative confounding from multiple comorbidities that was relieved by introducing the biological measures.

Previous studies have rarely examined the association between insomnia and falls in middle-aged adults, nor reported age-specific associations for insomnia and falls.

Table 2 Sociodemographics, lifestyle, medication use, comorbidities, and sleep characteristics of Puerto Rican adults, by falls in the past year ($n = 954$)

Characteristics (categorical variables)	All participants ($n = 954$) (%)	No falls in the past year ($n = 651$) (%)	Falls in the past year ($n = 303$) (%)
Sociodemograhpic and lifestyle			
Women (yes)	71.4	67.6**	79.5**
Smoking (yes)	20.7	20.6	20.9
Alcohol consumption (yes)	33.9	35.8*	29.6*
Bone fracture history (yes)	28.2	24.8**	35.3**
Hip fracture history (yes)	1.5	0.9*	2.6*
Medication use			
Antidepressants	37.1	34.4**	42.9**
Antianxiety agents	24.4	22.4*	28.7*
Antipsychotics	9.6	8.8	11.6
Antihistamines	13.6	12.9	15.2
Comorbidities			
Limitation in ADLs	24.3	20.1**	33.3**
Limitation in IADLs	8.4	6.8**	12.0**
Diabetes	43.0	41.6	45.9
Hypertension	77.5	76.1[a]	80.5[a]
Arthritis	61.7	57.8**	70.3**
Osteoporosis	16.4	15.3[a]	18.9[a]
CVDs	22.1	19.1**	28.5**
Stroke	5.3	5.5	4.6
Respiratory diseases	46.4	43.9*	51.7*
Liver/gallbladder diseases	22.5	20.8*	26.2*
Kidney diseases	15.6	13.1**	20.9**
Gastrointestinal diseases	41.6	37.8**	50.0**
Cancers	7.6	7.7	7.3
Eye diseases	30.7	28.9*	34.7*
Parkinson's diseases	0.5	0.3	1.0
Seizures	5.3	4.5[a]	7.0[a]
Sleep variables			
Insomnia disorders	15.5	13.4**	20.2**
Difficulty falling asleep	39.8	37.1**	46.0**
Difficulty maintaining asleep	36.7	34.4*	42.1*
Early awakenings	39.7	35.8**	48.3**
Unrested in the morning	21.9	20.5[a]	25.2[a]
Sleep ≤6 h/day	47.7	45.1*	53.4*
Daytime sleepiness	23.7	23.5	24.2
Snoring	46.9	46.6	47.5

Cross-tabulation with Chi-square test was used to compare the percentage differences of variables between the two groups

ADLs Activities of Daily Living, *IADLs* Instrumental Activities of Daily Living, *CVDs* cardiovascular diseases

[a] $p < 0.10$; * $p < 0.05$; ** $p < 0.01$

Mesas et al. reported an association between short or long sleep duration and falls in adults older than 75 years, but not in adults of 68–75 years [15]. Older age is known to be associated with increased risk of falls [37], probably due to muscle weakness and poor postural control, poor vigilance, and slower reaction time, all of which may partially explain why the association between insomnia and falls is stronger in older adults.

Consistent with our findings, several studies have reported association between sleep duration and falls in

Table 3 Insomnia and falls distribution across age and gender groups among Puerto Rican adults ($n = 954$)

	Insomnia disorder (yes)	Falls in the past year (yes)
Age		
≥60 years ($n = 439$)	11.0 % ($n = 48$)**	35.3 % ($n = 155$)*
<60 years ($n = 515$)	19.5 % ($n = 100$)**	28.7 % ($n = 148$)*
Gender		
Women ($n = 681$)	16.5 % ($n = 112$)	35.4 % ($n = 241$)**
Men ($n = 273$)	13.2 % ($n = 36$)	22.7 % ($n = 62$)**

* $p < 0.05$; ** $p < 0.01$

Table 4 Poisson regression models for the association of insomnia with falls, recurrent falls, and fractures

	Model 1 PR (95 % CI)	Model 2 PR (95 % CI)	Model 3 PR (95 % CI)	Model 4 PR (95 % CI)	Model 5 PR (95 % CI)	Model 6 PR (95 % CI)
Falls						
Insomnia disorders	1.39 (1.12–1.74)**	1.36 (1.09–1.70)**	1.33 (1.07–1.67)*	1.19 (0.94–1.50)	1.34 (1.06–1.69)*	1.32 (1.04–1.68)*
Age	1.02 (1.00–1.03)*	1.02 (1.00–1.03)*	1.02 (1.01–1.03)**	1.01 (1.00–1.03)[a]	1.01 (1.00–1.03)	1.01 (1.00–1.03)[a]
Gender (female)	1.53 (1.20–1.94)**	1.50 (1.17–1.92)**	1.44 (1.11–1.86)**	1.39 (1.06–1.83)*	1.47 (1.10–1.96)*	1.49 (1.11–2.01)**
Recurrent falls						
Insomnia disorders	1.31 (0.90–1.91)	1.24 (0.85–1.81)	1.17 (0.79–1.72)	1.07 (0.72–1.60)	1.24 (0.82–1.88)	1.19 (0.77–1.84)
Age	1.01 (0.99–1.03)	1.01 (0.99–1.03)	1.01 (0.99–1.04)	1.00 (0.98–1.03)	1.00 (0.97–1.03)	1.00 (0.97–1.03)
Gender (female)	2.57 (1.61–4.08)**	2.12 (1.31–3.42)**	2.00 (1.22–3.29)**	1.78 (1.07–2.95)*	1.63 (0.96–2.77)[a]	1.71 (0.98–2.98)
Fractures						
Insomnia disorders	1.15 (0.49–2.73)	0.87 (0.36–2.11)	0.87 (0.36–2.08)	0.76 (0.30–1.93)	0.82 (0.29–2.34)	1.03 (0.33–3.24)
Age	1.05 (1.01–1.10)**	1.04 (1.00–1.09)[a]	1.03 (0.99–1.08)	1.03 (0.98–1.09)	1.02 (0.96–1.10)	1.04 (0.97–1.12)
Gender (female)	0.96 (0.49–1.91)	1.07 (0.50–2.28)	1.19 (0.51–2.77)	1.18 (0.49–2.88)	1.05 (0.37–2.94)	1.76 (0.65–4.75)

[a] $p < 0.10$; * $p < 0.05$; ** $p < 0.01$

PR prevalence ratio, *CI* confidence interval

Model 1 was adjusted for age and gender

Model 2 was adjusted for age, gender, BMI, smoking, alcohol consumption, physical activity, bone fracture history, and hip fracture history

Model 3 was adjusted for variables in Model 2, and depression, cognitive function, and perceived stress, and use of antidepressants, antianxiety agents, antipsychotics, and antihistamines

Model 4 was adjusted for variables in Model 3, and limitation in ADLs, IADLs, diabetes, hypertension, arthritis, osteoporosis, CVDs, stroke, respiratory diseases, liver/gallbladder diseases, kidney diseases, gastrointestinal diseases, cancers, eye diseases, Parkinson's diseases, and seizures

Model 5 was adjusted for variables in Model 4, and CPR, IL-6, urinary cortisol, and BMD femur

Model 6 was adjusted for variables in Model 5, and sleep duration, snoring, and daytime sleepiness

women but not in men [14, 15]. Female gender has been consistently reported as a risk factor for falls [1, 15, 40], even though some studies reported different results with institutionalized older adults [37]. The disparities in the association of insomnia and falls between women and men may be explained by the gender differences in body constitution, such as muscular strength, which were not assessed in our study. Further studies are warranted to understand this potential gender difference in insomnia–fall relationship. However, there is also possibility that the gender-stratified sample size was not big enough to draw a conclusion in men.

Table 5 Poisson regression models for the age- and gender-specific associations between insomnia and falls

	Model 1 PR (95 % CI)	Model 2 PR (95 % CI)	Model 3 PR (95 % CI)	Model 4 PR (95 % CI)	Model 5 PR (95 % CI)	Model 6 PR (95 % CI)
Age						
≥ 60 y (n = 439) Insomnia disorders	1.56 (1.16–2.11)**	1.51 (1.11–2.06)**	1.49 (1.09–2.04)*	1.36 (0.97–1.91)[a]	1.32 (0.93–1.87)	1.27 (0.89–1.80)
< 60 y (n = 515) Insomnia disorders	1.28 (0.94–1.74)	1.23 (0.91–1.66)	1.18 (0.86–1.60)	1.02 (0.75–1.39)	1.18 (0.87–1.60)	1.26 (0.91–1.73)
Gender						
Women (n = 681) Insomnia disorders	1.37 (1.08–1.73)*	1.37 (1.08–1.73)*	1.36 (1.07–1.73)*	1.19 (0.93–1.53)	1.37 (1.07–1.75)*	1.37 (1.07–1.76)*
Men (n = 273) Insomnia disorders	1.49 (0.86–2.59)	1.35 (0.78–2.32)	1.27 (0.69–2.34)	1.20 (0.66–2.21)	1.17 (0.62–2.20)	1.04 (0.57–1.91)

[a] $p < 0.10$; * $p < 0.05$; ** $p < 0.01$

PR prevalence ratio, *CI* confidence interval

Model 1, 2, 3, 4, 5, and 6 were adjusted as Model 1, 2, 3, 4, 5, and 6 in Table 4

Strengths and limitations

The strengths of the study include a relatively large number of study participants, a wide range of covariates assessed, covering both survey and biological measures, and assessment of age- and gender-specific differences in the association between insomnia and falls. This study has some methodological limitations. First, the generalizability of the study may be limited because the participants were 46–79 years Puerto Rican adults living in Boston, MA. This study did not include Puerto Rican adults older than 79 years, although this older age group is likely to suffer more falls and to have more serious consequences from falls [15, 37]. In addition, the cross-sectional design does not allow us to draw causal relationships. Future analyses of longitudinal data from diverse and older populations are needed to verify the study findings. Second, about one-fourth of the participants from the BPRHS 2-year follow-up did not complete the BPROS, but we confirmed that there were few substantial differences between participants and non-participants in sociodemographic or lifestyle factors, or mental status. Third, assessment of insomnia and falls was based on retrospective self-report, which may include misclassification and underreporting. Future use of objective measures of sleep with a prospective study design could reduce the information bias from self-reported retrospective data. Fourth, assessment of the outcome of falls was limited to fracture in this study. Future assessment of other consequences of falls, such as physical injuries, functional decline, and health service use, is important to understand the broader association between insomnia and falls. Lastly, although we adjusted for multiple risk factors for insomnia or falls, we cannot exclude the possibility of residual confounding. For example, we did not collect information on polyurea, heart failure, and dysrhythmia.

Conclusion

In conclusion, insomnia was associated with increased risk of falls in Boston Puerto Rican adults, 60 years or older, and in Puerto Rican women, aged 46–79 years. Insomnia is prevalent in community-dwelling middle-aged and older adults and may have significant negative consequences [9, 41]. Especially for a subgroup of the US Hispanic population, the prevalence of insomnia and the negative consequences, such as falls, are suspected to be higher, considering the higher prevalence of risk factors, such as obesity, type 2 diabetes, hypertension, arthritis, and depression [26]. The health and safety of this population deserves critical attention from clinicians and researchers. From a clinical perspective, results from this study encourage the assessment of insomnia as an important risk factor for falls, and the consideration of age and gender when assessing the relationship between insomnia and falls in Puerto Ricans. In practice, well-designed evidence-based non-pharmacological interventions, such as meditation, yoga, Tai Chi, acupuncture, or acupressure [42], to treat insomnia and improve sleep quality may reduce the risk of falls in this population. This study reported

association between insomnia and falls, but non-association between use of sleep medicine and falls. Future research is needed to assess whether effective pharmacological treatment of insomnia is associated with reduced risk of falls in the elderly. In addition, using more comprehensive and objective measures of sleep is valuable to assess whether other disorders, such as sleep apnea, contribute to these relationships.

Acknowledgments The Boston Puerto Rican Health Study was funded by the US National Institute of Health Grants: P01 AG023394, P50 HL105185, and R01 AG027087. None of the sponsors participated in the study design or data collection, analysis, or interpretation.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval The Boston Puerto Rican Health Study (BPRHS) and the Boston Puerto Rican Osteoporosis Study (BPROS) were approved by the Institutional Review Boards at Tufts Medical Center and Northeastern University (IRB #6629, #6763, #10-02-22). The current analysis was further approved by the University of Massachusetts Lowell Institutional Review Board (IRB #13-109). All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the Boston Puerto Rican Health Study (BPRHS) and the Boston Puerto Rican Osteoporosis Study (BPROS).

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