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ORIGINAL ARTICLE

Severe low back or lower limb pain is associated with recurrent falls among older Australians

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Abstract

Background: Few studies have explored the impact of low back or lower limb pain severity on recurrent (≥2) falls in older adults.

Objectives: Investigate the association between the severity of low back or lower limb pain, and ≥2 falls or falls-related injuries.

Methods: Community-dwelling Australian males and females in the ASPREE Longitudinal Study of Older Persons (ALSOP), aged ≥70 years. Self-reported, cross-sectional questionnaire data regarding number of falls and falls-related injuries in the last 12 months; and sites and severity of pain experienced on most days. Adjusted relative risks (RR) were estimated from multivariable Poisson regression models, for males and females separately.

Results: Of 14,892 ALSOP participants, 13% (n = 1983) reported ≥2 falls ('recurrent fallers') in the last 12 months. Males and females who reported severe low back, or severe lower limb pain on most days were more likely to report ≥2 falls in the last 12 months compared to those with mild pain (lower back: males RR = 1.70 and females RR = 1.5, p = 0.001; lower limb: males RR = 2.0, $p < 0.001$ and females RR = 1.4, p = 0.003). Female recurrent fallers who reported severe low back (RR = 1.3, $p = 0.029$) or lower limb (RR = 1.2, $p = 0.024$) pain on most days were more likely to report a falls-related injury in the last 12 months compared to females with mild pain.

Conclusion: Severe low back or lower limb pain was associated with an increased likelihood of recurrent falls (males/females) or falls-related injuries (females only). Assessment of severe low back and lower limb pain should be considered as a priority when undertaking falls-risk evaluation.

Significance: Severe low back pain, or severe lower limb pain is associated with an increased likelihood of recurrent falls in older males and females, and an increased likelihood of falls-related injuries in older female recurrent fallers. Assessment and management of severe low back and lower limb pain should be prioritized when undertaking falls-risk assessment. Future longitudinal research is required to further interrogate this relationship and its underlying mechanisms.

1 | INTRODUCTION

Falls are a significant public health issue in Australia for community-dwelling older adults. One in three people aged over 65 years experience at least one fall per year (Australian & New Zealand Falls Prevention Society, 2020). Falls are associated with injury and disability (Finlayson & Peterson, 2010), fear of falling (Patel et al., 2014), and impact on mobility and quality of life (Finlayson & Peterson, 2010). An estimated 684,000 fatal falls occur annually in the world, where death rates are highest among those aged over 60 years (World Health Organization, 2021). Older women are more prone to falls and increased injury severity (World Health Organization, 2021). Recurrent falls, defined as two or more falls in a 12-month period (Dai et al., 2018; Jehu et al., 2020; Waldron et al., 2012), are associated with more serious morbidity such as mobility limitation and hospitalization, and mortality, compared to single fall events (Dai et al., 2018). Therefore, modifiable risk factors associated with recurrent falls warrant further investigation (Cederbom & Arkkukangas, 2019).

Pain is also a major health issue for community-dwelling older adults, with an international prevalence of 45%–80% (Cederbom & Arkkukangas, 2019; Welsh, Clarson, et al., 2019). In addition to being strongly associated with frailty, reduced physical function, loss of independence, psychological distress, poor quality of life and mortality, pain is an independent risk factor for falling (Blyth & Noguchi, 2017; Cederbom & Arkkukangas, 2019; Hartvigsen et al., 2018; Valderrama-Hinds et al., 2018; Welsh, Clarson, et al., 2019). Not only is pain commonly reported in older adults (Edeer & Tuna, 2012; Gilmartin-Thomas et al., 2020; Wong et al., 2017), previous studies have found that single body site pain located in the low back, hip, knee or foot (Brenton-Rule et al., 2016; Doré et al., 2015; Edeer & Tuna, 2012; Gilmartin-Thomas et al., 2020; Lee et al., 2018; Marshall et al., 2017; Munch et al., 2015; Stubbs et al., 2015) are particularly associated with a higher risk of falling. Low back pain has been identified as a leading cause of disability globally (Blyth & Noguchi, 2017), with a 1-year prevalence of 13%–50% in community-dwelling older people (Wong et al., 2017). Furthermore, among people with back pain, the majority have low back pain only (more than 60%) (Marshall et al., 2017). Pain in the lower extremities has also been found to be prevalent and disabling in the older population, where the prevalence of hip pain has been reported to be between 30% and 34%, the prevalence of knee pain between 21% and 39%, and the prevalence of foot pain between 20% and 50% (Hicks et al., 2020; Menz et al., 2013; Stubbs, Binnekade, et al., 2014; Welsh, Clarson, et al., 2019). Low back and lower limb pain increase gait abnormality, which are more likely to increase risk of falls than pain in other regions of the body (Lamoth & Daffertshofer, 2006; Menz et al., 2013). It is, therefore, worthwhile to investigate and focus on low back and lower limb pain in future research.

Although several studies have shown that severe pain is associated with falls (Welsh, Clarson, et al., 2019), these were mostly focused on general pain or pain of one body site alone (Awale et al., 2017; Cai et al., 2020; Crowe et al., 2017; Leveille et al., 2009; Marshall et al., 2017), where comparison of different pain severity in different body sites within one study was very limited (Leveille et al., 2009; Marshall et al., 2017). Kitayuguchi et al. (2017), being one of the few studies that compared different severity of pain (none, mild, severe, very severe), reviewed pain in the low back and the knees, however, it did not investigate falls-related injury, did not include foot pain, and did not focus on the older aged population (included people 60 years and older (Kitayuguchi et al., 2017); while foot pain had previously been found to increase the odds of recurrent falls by more than 60% (Awale et al., 2017). While Marshall et al. (2017) investigated differing pain severity, only one body site was investigated (the back) and analyses were conducted in men only. Since the prevalence of low back and lower limb pain are both high in older populations, it would be important to know whether pain severity in these body sites is a red flag for recurrent falls in this cohort.

Few studies have analysed the association between pain and recurrent falls, and these have often been conducted in 'younger' older adults (minimum age of 60 years). Ageing can alter the experience of pain—pain perception, modulation and expression—due to age-related changes to neural, immune, humoral and psychological systems (Blyth & Noguchi, 2017). Since the prevalence of both pain and falls are higher in those classified as the 'older' old (aged at least 80 years) (Gálvez-Barròn et al., 2020; Rao, 2005), particularly when the prevalence of falls among people aged in their 70th decade are twice that among people aged in their 60th decade (Hicks et al., 2020; Waldron et al., 2012), this study can add to the currently available evidence by focusing on an 'older' group of older people who were at least 70 years of age.

Gender differences in pain prevalence have also been identified in previous studies, with females reporting higher levels of pain than males (Gutiérrez Lombana & Gutiérrez Vidál, 2012; Leveille et al., 2005; Pieretti et al., 2016) and having a higher risk of falling (Ambrose et al., 2013; Deandrea et al., 2010). However, the available evidence from the literature on gender differences in the association between pain and falls has been inconsistent. For example, while Gale et al. (2018) found that higher level of pain was associated with falls for both genders in a longitudinal study, Welmer et al. (2017) found that pain appeared to be associated with the risk of injurious falls in men but not in women despite a higher prevalence of pain and higher rate of severe pain among women participants. On the contrary, Cai et al. found that the association between chronic pain and injurious falls was only significant in women but not in men (Cai et al., 2020). The causes attributed to the sex differences observed are many and complex, most commonly explained by a biopsychosocial model (Bartley & Fillingim, 2013). Some of the biological factors include women being more commonly affected by arthritis, differences in the endogenous opioid system, different nociceptive sensitivity (Bartley & Fillingim, 2013; Leveille et al., 2005; Welmer et al., 2017), and the eventual impact on balance, mobility limitation and disability (Bartley & Fillingim, 2013; Welmer et al., 2017). Psychosocial factors include different pain coping strategies, sociocultural belief and acceptance, history of exposure to environmental stress and trauma (Bartley & Fillingim, 2013; Leveille et al., 2005), higher levels of fear of falling and behaviours of activity avoidance more commonly occurred in women (Bartley & Fillingim, 2013; Cai et al., 2020; Welmer et al., 2017).

The present study aimed to primarily examine the association between the severity of low back pain, or lower limb pain, with self-reported recurrent (≥2) falls in the last 12 months, in community-dwelling Australian males and females aged at least 70 years. With respect to these 'recurrent fallers', the secondary aim of the present study was to examine the association between the severity of low back pain, or lower limb pain, with self-reported falls-related injuries in the last 12 months. In light of few studies exploring the contribution of low back pain and lower limb pain to recurrent falls in an older aged population, it is a novelty of this study to focus on the older aged population who were community-dwelling, to include the elements of comparison of different pain patterns between genders, and to compare the impact of pain severity in two important sites of body pain—low back and lower limb—on the risk of recurrent falls and falls-related injuries within one study, which had not been done before. With a greater understanding of how falls-related risk factors can differentially impact males and females, or relatively 'younger' or 'older' aged cohorts, clinicians can provide targeted, patient-centred falls-risk assessment and management.

2 | METHODS

2.1 | Design and participants

The present study analysed baseline Australian data from the ASPirin in Reducing Events in the Elderly (ASPREE) study (McNeil et al., 2018) and the ASPREE Longitudinal Study of Older Persons (ALSOP, a sub-study of the ASPREE study) (McNeil et al., 2019).

ASPREE was a randomized, double-blind, placebo-controlled primary prevention clinical trial involving 16,703 community-dwelling Australians aged at least 70 years, which investigated whether low dose aspirin extended the duration of disability-free and dementia-free survival (ASPREE Investigator Group, 2013; McNeil et al., 2018).

Recruitment of Australian participants for ASPREE predominantly occurred via general practice, with general practitioners registered as ASPREE co-investigators. Invitation letters were sent to potential participants after a search through general practitioner clinical databases, guided by inclusion and exclusion criteria (ASPREE

Investigator Group, 2013; Daut et al., 1983; Gale et al., 2018; McNeil et al., 2018, 2019).

Inclusion criteria for ASPREE included fluency in English and an ability to attend study clinic visits; while exclusion criteria included: history of a diagnosed cardiovascular disease event defined as myocardial infarction, heart failure, angina pectoris, stroke, transient ischaemic attack, 50% carotid stenosis or previous carotid endarterectomy or stenting, coronary artery angioplasty or stenting, coronary artery bypass grafting or abdominal aortic aneurysm; a clinical diagnosis of atrial fibrillation; serious illness likely to cause death within the next 5 years; a current or recurrent condition with a high risk of major bleeding; anaemia (haemoglobin >12 g/dl males, >11 g/dl females); an absolute contraindication or allergy to aspirin; current participation in an ongoing clinical trial; current use of aspirin for secondary prevention; current continuous use of other antiplatelet drug or anticoagulant; a systolic blood pressure ≥180 mm Hg and/or a diastolic blood pressure ≥105 mm Hg; a history of dementia or a Modified Mini-Mental State Examination (3MS) score ≤77 (Bland & Newman, 2001); severe difficulty or an inability to perform any one of the six Katz activities of daily living; and pill-taking compliance ≤80% during a 4-week placebo run-in phase (McNeil et al., 2018).

Potential participants were asked to respond to a toll-free telephone number to complete further study screening, with suitable candidates subsequently invited to an initial study visit for assessment and collection of baseline data. Participants were then randomized 1:1 to aspirin or placebo (ASPREE Investigator Group, 2013).

Following randomization (recruitment 2010–2014), a 14-page baseline ALSOP Medical Health Questionnaire was posted to an eligible subset of the Australian ASPREE participants ($n = 16{,}439$) who were alive and allowed active researcher contact, along with a postal-paid return envelope. Participants were prompted to return their completed questionnaires at the annual ASPREE study face-to-face clinic visits and three-monthly follow-up telephone calls (McNeil et al., 2019). The baseline ALSOP Medical Health Questionnaire collected health-related data including self-reported pain and falls (McNeil et al., 2019).

2.2 | Variables

2.2.1 | Pain

Self-reported data regarding pain experienced on most days were collected from the 14-page baseline ALSOP Medical Health Questionnaire. The pain-related questions were developed following a review of existing pain measurement instruments (i.e. numerical pain rating scales and the Brief Pain inventory Hjermstad et al., 2011), and were piloted among 20 older people and modified for ease of interpretation by participants.

Pain-related questions included:

- Do you experience pain on most days? Response options: Yes or No. (Respondents were asked to complete the subsequent questions if they answered 'Yes').
- Where in your body do you feel this pain? Marking all that applies. Response options: Head (including headache, face, eyes, ears and mouth), neck, chest, upper back (including shoulder blades, shoulders and upper arms), lower arm (including elbows, wrists and hands), lower back, abdomen or stomach, hips or groin, between legs, knees, lower legs (including ankles and feet).
- How severe has your pain been most of the time in the last week? Response options: 0 (no pain), 1, 2, 3, 4, 5, 6, 7, 8, 9 or 10 (maximum pain).

The present study analysed participants who reported pain on most days in the 'low back', or in the 'lower limbs' which comprised the hips or groin, between the legs, knees and lower legs (including ankles and feet). Based on the published literature, responses to the numerical pain scale were categorized into 'mild pain' (score 1–3), 'moderate pain' (score 4–6) and 'severe pain' (score 7–10) in the present study (Boonstra et al., 2016; Breivik et al., 2008; Gilmartin-Thomas, Cicuttini, et al., 2020; Hjermstad et al., 2011; Kitayuguchi et al., 2017).

2.2.2 | Falls and falls-related injuries

Self-reported data regarding falls and falls-related injuries were collected from the 14-page baseline ALSOP Medical Health Questionnaire.

Falls-related questions included:

- In the past year have you had any falls? (please include any slip or trip in which you lost your balance & landed on the floor/ground). Response options: Yes or No.
- If yes, how many falls in total have you had in the last 12 months? Response options: 1, 2, 3, 4 or more.
- In the last 12 months have any of the falls caused an injury such as a large bruise, cut or broken bone/ fracture? Response options: Yes or No.

In the present study, recurrent falls were defined as ≥2 falls in the last 12 months.

2.2.3 | Adjusted covariates

Covariates were selected based on those included in previous studies investigating pain and falls (Boonstra et al., 2016; Kitayuguchi et al., 2017; Munch et al., 2015; Patel et al., 2014; Valderrama-Hinds et al., 2018). Age, smoking status, alcohol use, body mass index (BMI), presence of depressive symptoms and years of education were all collected by ASPREE research staff (ASPREE Investigator Group, 2013). Frequency of analgesic use was collected via the 14-page baseline ALSOP Medical Health Questionnaire.

History of smoking and alcohol use was self-reported by participants and classified in the present study as 'yes' (including 'current' user) or 'no' (including 'former' or 'never' user) (ASPREE Investigator Group, 2013). Height was measured without shoes standing against a wall using a calibrated stadiometer and weight was measured following the removal of excess clothing with calibrated scales (ASPREE Investigator Group, 2013). The BMI was calculated using weight in kilogram/(height in metres square) and classified in the present study as underweight (BMI < 18.5), normal (BMI 18.5–24.9), overweight (BMI 25.0–29.9) and obese (BMI ≥30.0) according to World Health Organization thresholds (ASPREE Investigator Group, 2013; World Health Organization, 2020).

The presence or absence of depressive symptoms was assessed by the Center for Epidemiologic Studies-Depression 10 (CES-D) self-reported questionnaire, where a CES-D ≥ 8 indicated the presence of depressive symptoms in the present study (Baron et al., 2017; Radloff, 1977). The frequency of using analgesics was collected by the question 'How often do you take medication for pain?', with response options including 'Never', 'Rarely (less than once a month)', 'Sometimes (1–3 times a month)', 'Often (once a week or more)', or 'Always (most days)'. Years of education were self-reported and classified in the present study as '<12 years' or '≥12 years'.

2.2.4 | Additional demographic variables

In the ASPREE study, hypertension was defined as treatment for high blood pressure or blood pressure of >140/90 mmHg at ASPREE study entry (McNeil et al., 2018). Diabetes was based on participants' self-report of diabetes mellitus or a fasting glucose level of ≥126 mg per deciliter (≥7 mmol per litre) or receiving treatment for diabetes (McNeil et al., 2018). Dyslipidemia was defined as receiving cholesterol-lowering medication or as a serum cholesterol level of ≥212 mg per deciliter (≥5.5 mmol per litre) or as a low-density lipoprotein level of >160 mg per deciliter (>4.1 mmol per litre) (McNeil et al., 2018). Limited information regarding participants' self-reported physical activity was collected in the ALSOP Social Health Questionnaire, which accompanied the ALSOP Medical Health Questionnaire. Participants were asked: Thinking about how much physical activity you do at present, in a typical week which of the following best describes your level of activity? Response options: I would rarely/never do any physical activity; I would do no more than LIGHT physical activity; I would do no more than MODERATE physical activity; and I do regular VIGOROUS physical activity.

2.3 | Statistical analysis

STATA 17 was used to complete all statistical analyses (StataCorp. 2021. Stata Statistical Software: Release 17). Characteristics of the study population were summarized using descriptive statistics. Adjusted relative risks (RR) were estimated from multivariable Poisson regression models, which were used to summarize the relationship between the severity of pain and recurrent falls, or falls-related injuries. Standard errors were calculated using the robust variance formula.

To enhance the interpretability of findings (Cummings, 2009), Poisson regression models were used to estimate RRs (Chen et al., 2018) from the dichotomous outcome data. This is in contrast to using logistic regression models, which in general, estimate odds ratios (Sroka & Nagaraja, 2018).

The Poisson regression model was chosen over alternative models to estimate RRs (such as the log-binomial model) as it is less sensitive to outliers when estimating RRs (Chen et al., 2018) for common binary outcomes. Poisson regression with the use of robust standard errors has been shown to produce consistent estimates as would be obtained from the log-binomial model (Carter et al., 2005). Hence the Poisson approach is valid despite any potential violations of the underlying assumptions of Poisson regression. Robust standard errors with Poisson regression has been recommended (Cameron & Trivedi, 2009) when considering alternative approaches to the negative binomial model.

Analyses were adjusted for age, smoking status, alcohol use, BMI, presence of depressive symptoms, frequency of analgesic use and years of education. Previously conducted research guided the choice of covariates, as well as the need to avoid over adjustment (Zhang, 2014). Physical function indicators such as gait speed, grip strength and activities of daily living were not controlled for in the presented analyses (although they were included in unshown sensitivity analyses and confirmed to have not affected the results significantly), as previous research did not find material difference in the association between pain and falls risk when considering these additional factors (Ambrose et al., 2013; Leveille et al., 2009; Marshall et al., 2017; Munch et al., 2015). Similarly, comorbidities were not included in the final model used in this study since this study population were deemed healthy at baseline, having excluded people with cardiovascular diseases and those with severe difficulty or an inability to perform any one of the six Katz activities of daily living (Bland & Newman, 2001; McNeil et al., 2018). Analyses were conducted separately for males and females due to differences in reporting of pain and falls (Ambrose et al., 2013; Deandrea et al., 2010).

Data relating to the number of falls reported by participants were categorized to isolate recurrent fallers (2, 3, 4 or more falls) from those reporting no falls. This categorization was undertaken to address the present study's primary and secondary aims, which centred around recurrent fallers (defined as ≥2 falls).

The present analyses categorized variables to enhance interpretability in Table 1 (Characteristics of respondents who reported ≥2 falls in the last 12 months). For consistency, these categories were maintained for analyses presented in Tables 2 and 3.

Sensitivity analyses were conducted, where age, smoking status, alcohol status, body mass index, frequency of analgesic use and years of education were controlled for in the form that they were originally recorded at data collection. Depressive symptoms were maintained as a categorical variable for ease of interpretability.

To address the cross-sectional nature of analyses associated with the primary study aim, which involved examining the association between severity of low back pain, or lower limb pain with self-reported recurrent (≥2) falls in the last 12 months, sensitivity analyses excluded participants who reported ≥2 falls and also reported a falls-related injury.

3 | RESULTS

3.1 | Prevalence of ≥2 falls in the last 12 months

The baseline ALSOP Medical Health Questionnaire was returned by 91% of ASPREE participants (14,892 of 16,439 eligible Australian participants). Of the 14,892 baseline ALSOP Medical Health Questionnaire respondents, 15% (n = 2220) reported only 1 fall and 13% (n = 1983) reported ≥2 falls ('recurrent fallers') in the last 12 months.

Of these 1983 'recurrent fallers', 60% were female (n = 1181) and aged on average 76 years, 51% (n = 1012) had ≥12 years of education, 40% (n = 799) were overweight and 34% (n = 676) were obese at baseline, 97% (n = 1925) were former or never smokers, 78% (n = 1538) were current alcohol users, 16% (n = 312) were categorized as having depressive symptoms, 32% used medication for pain 'often' or 'always', 34% reported low back pain on most days (which was severe in 8%, n = 157), 42% reported lower limb pain on most days (which was severe in 9%, n = 181), and 47% (n = 929) reported a falls-related injury. Compared to males, females were 33% more likely to report ≥2 falls in the last 12 months (RR = 1.33, 95% confidence interval [CI] 1.2–1.4, p < 0.001, Table 1).

3.2 | Association between the severity of low back or lower limb pain experienced on most days and ≥2 falls in the last 12 months

Males or females who reported severe low back pain on most days were 70% (males) and 50% (females) more likely to report ≥2 falls in the last 12 months compared to males or females who reported mild low back pain on most days (males RR = 1.70, 95% CI = 1.3–2.4 and females RR = 1.5, 95% CI 1.2–1.9, p = 0.001, Table 2).

Males or females who reported severe lower limb pain on most days were 100% (males) and 40% (females) more likely to report ≥2 falls in the last 12 months compared to males or females who reported mild lower limb pain on most days (males RR = 2.0, 95% CI = 1.5–2.7, p < 0.001 and females RR = 1.4, 95% CI 1.1–1.7, p = 0.003, Table 2).

3.3 | Association between the severity of low back or lower limb pain experienced on most days and falls-related injury in the last 12 months (in those reporting ≥2 falls in the last 12 months)

Female recurrent fallers who reported severe low back pain on most days were 30% more likely to report a falls-related injury in the last 12 months compared to female recurrent fallers who reported mild low back pain on most days (RR = 1.3, 95% CI 1.02–1.56, p = 0.029, Table 3). No significant association was found among males.

Female recurrent fallers who reported severe lower limb pain on most days were 20% more likely to report a falls-related injury in the last 12 months compared to female recurrent fallers who reported mild lower limb pain on most days (RR = 1.2, 95% CI 1.03–1.50, p = 0.024,

TABLE 1 Characteristics of respondents who reported ≥2 falls in the last 12 months

	No falls		≥2 falls	
Characteristics	**Males (*n* = 5133)**	**Females (*n* = 5377)**	**Males (*n* = 802)**	**Females (*n* = 1181)**
Age (years)				
70–80	4454 (87)	4577 (85)	656 (82)	981 (83)
≥80	679 (13)	800 (15)	146 (18)	200 (17)
Years of education				
<12	2416 (47)	2879 (54)	387 (48)	584 (49)
≥12	2717 (53)	2497 (46)	415 (52)	597 (51)
Body mass index category				
Underweight <18.5	14 (0.3)	45 (0.8)	0 (0)	9 (0.8)
Normal range 18.5–24.9	1111 (22)	1647 (31)	183 (23)	302 (26)
Overweight 25.0–29.9	2737 (53)	2102 (39)	382 (48)	417 (35)
Obese ≥30.0	1253 (24)	1558 (29)	233 (29)	443 (38)
Smoking status				
Current	184 (4)	143 (3)	27 (3)	31 (3)
Former or Never	4949 (96)	5234 (97)	775 (97)	1150 (97)
Alcohol use				
Current	4418 (86)	4012 (75)	669 (83)	869 (74)
Former or Never	715 (14)	1365 (25)	133 (17)	312 (26)
Hypertension				
Yes	3889 (76)	3976 (74)	604 (75)	865 (73)
No	1244 (24)	1401 (26)	198 (25)	316 (27)
Diabetes				
Yes	584 (11)	398 (7)	113 (14)	122 (10)
No	4549 (89)	4979 (93)	689 (86)	1059 (90)
Dislipidaemia				
Yes	2941 (57)	4156 (77)	415 (52)	916 (78)
No	2192 (43)	1221 (23)	387 (48)	265 (22)
Depressive symptoms				
Yes	328 (6)	502 (9)	109 (14)	203 (17)
No	4804 (94)	4873 (91)	693 (86)	978 (83)
Physical activity				
Rarely/never	50 (1)	63 (1)	11 (1)	29 (2)
Light	1049 (20)	1670 (31)	219 (27)	410 (35)
Moderate	2391 (47)	2256 (42)	342 (43)	434 (37)
Vigorous	886 (17)	582 (11)	127 (16)	116 (10)
Frequency of using medication for pain				
Never	1412 (28)	726 (14)	147 (18)	89 (8)
Rarely or Sometimes	2946 (57)	3396 (63)	438 (55)	627 (53)
Often or Always	653 (13)	1149 (21)	199 (25)	439 (37)
Site of pain experienced on most days[a]				
Low back	972 (19)	1310 (24)	246 (31)	434 (37)
Lower limb	1167 (23)	1474 (27)	299 (37)	538 (46)

(Continues)

TABLE 1 (Continued)

Characteristics	No falls Males (n = 5133)	No falls Females (n = 5377)	≥2 falls Males (n = 802)	≥2 falls Females (n = 1181)
Severity of low back pain experienced on most days[b]				
Mild	491 (10)	478 (9)	96 (12)	112 (9)
Moderate	388 (8)	596 (11)	100 (12)	211 (18)
Severe	84 (2)	213 (4)	47 (6)	110 (9)
Severity of lower limb pain experienced on most days[b]				
Mild	571 (11)	559 (10)	110 (14)	154 (13)
Moderate	480 (9)	667 (12)	122 (15)	260 (22)
Severe	101 (2)	223 (4)	62 (8)	119 (10)
Falls-related injury				
Yes	N/A	N/A	270 (34)	659 (56)
No	N/A	N/A	523 (65)	507 (43)

Note: Column entries may not sum to column totals due to missing values.

[a]May include respondents who reported pain in other body locations also.

[b]Pain severity categories: mild (1–3), moderate (4–6), severe (7–10).

TABLE 2 Association between severity of low back or lower limb pain experienced on most days with ≥2 falls in the last 12 months[a]

Exposure	≥2 falls in the last 12 months[b] (n = 1983)					
	Males (n = 802)			Females (n = 1181)		
	Relative risk	95% CI	p value	Relative risk	95% CI	p value
Low back pain experienced on most days[c,d]						
Mild	1.00 (reference)			1.00 (reference)		
Moderate[e]	1.1 (1.2)	0.9–1.4 (1.0–1.6)	0.430 (0.104)	1.2 (1.4)	1.0–1.5 (1.1–1.7)	0.038 (0.002)*
Severe[e]	1.7 (2.2)	1.3–2.4 (1.6–2.9)	0.001* (<0.001)*	1.5 (1.8)	1.2–1.9 (1.4–2.3)	0.001* (<0.001)*
Lower limb pain experienced on most days[c,d]						
Mild	1.00 (reference)			1.00 (reference)		
Moderate[e]	1.1 (1.2)	0.9–1.5 (1.0–1.6)	0.280 (0.071)	1.2 (1.3)	1.0–1.4 (1.1–1.5)	0.052 (0.003)
Severe[e]	2.0 (2.3)	1.5–2.7 (1.8–3.0)	<0.001* (<0.001)*	1.4 (1.6)	1.1–1.7 (1.2–2.0)	0.003* (<0.001)*

Note: () = adjusted for age alone.

[a]Analyses adjusted for age, smoking status, alcohol status, body mass index, depressive symptoms, frequency of analgesic use, years of education.

[b]Compared to respondents reporting no falls (n = 10,510).

[c]Pain severity categories: mild (1–3), moderate (4–6), severe (7–10).

[d]May include respondents who reported pain in other body locations also.

[e]Compared to the reference category (mild pain).

*Statistically significant at $p < 0.05$.

Table 3). No significant association was found among males.

3.4 | Sensitivity analyses

When participants who reported ≥2 falls and at least 1 falls-related injury were excluded from analyses, severe low back or severe lower limb pain was still significantly associated with reporting ≥2 falls in the last 12 months, in males. These sensitivity analyses support study findings of an association between severe low back or severe lower limb pain experienced on most days and subsequent falls. Despite a non-significant finding in females, these sensitivity analyses conservatively removed all recurrent fallers who reported any falls-related injury.

An additional sensitivity analysis identified that adjusted RRs were essentially unchanged when additional

TABLE 3 Association between severity of low back pain or lower limb pain experienced on most days with falls-related injury in the last 12 months (in those reporting ≥2 falls)[a]

	Falls-related injury in the last 12 months (in those reporting ≥2 falls)[b] $n = 929$					
	Males ($n = 270$)			Females ($n = 659$)		
Exposure	Relative risk	95% CI	*p* value	Relative risk	95% CI	*p* value
Low back pain experienced on most days[c,d]						
Mild	1.00 (reference)					
Moderate[e]	1.2 (1.3)	0.8–1.7 (0.9–1.8)	0.406 (0.202)	1.0 (1.0)	0.8–1.2 (0.8–1.2)	0.965 (0.940)
Severe[e]	1.1 (1.3)	0.7–1.7 (0.8–1.9)	0.577 (0.257)	1.3 (1.3)	1.02–1.6 (1.03–1.5)	0.029* (0.026)*
Lower limb pain experienced on most days[c,d]						
Mild	1.00 (reference)					
Moderate[e]	1.1 (1.2)	0.8–1.7 (0.9–1.8)	0.550 (0.256)	1.1 (1.1)	0.9–1.3 (0.9–1.3)	0.400 (0.384)
Severe[e]	1.2 (1.5)	0.8–1.9 (1.0–2.2)	0.308 (0.051)	1.2 (1.3)	1.03–1.5 (1.1–1.5)	0.024* (0.011)*

Note: () = adjusted for age alone.

[a]Analyses adjusted for age, smoking status, alcohol status, body mass index, depressive symptoms, frequency of analgesic use, years of education.

[b]Compared to no falls-related injury in the last 12 months (in those reporting ≥2 falls, $n = 1030$).

[c]Pain severity categories: mild (1–3), moderate (4–6), severe (7–10).

[d]May include respondents who reported pain in other body locations also.

[e]Compared to the reference category (mild pain).

*Statistically significant at $p < 0.05$.

covariates were adjusted for, including average baseline gait speed (3 m walk, seconds), average right and left baseline grip strength (Dynamometer, kg) and use of a walking aid (No vs Yes-cane, walking frame, other).

Similar results were obtained following sensitivity analyses (where age, smoking status, alcohol status, body mass index, frequency of analgesic use and years of education were controlled for in the form that they were originally recorded at data collection), noting that the p value for the association between severity of low back pain experienced on most days with falls-related injury in the last 12 months (in those reporting ≥2 falls) increased slightly to 0.065 from 0.029 (Table 3).

4 | DISCUSSION

This large-scale study of older, community-dwelling Australian males and females, has highlighted the increased likelihood of recurrent falls in those reporting severe low back pain, or severe lower limb pain on most days, compared to those reporting mild low back or lower limb pain on most days. Additionally, findings suggest that female recurrent fallers who reported severe low back pain, or severe lower limb pain on most days had a higher likelihood of reporting a falls-related injury. These findings are supported by the published literature (Awale et al., 2017; Leveille et al., 2009; Marshall et al., 2017; Welsh, Mallen, et al., 2019), adding in a unique element of specifically focusing on pain in the low back and lower limb. Our study findings support clinicians to investigate low back pain or lower limb pain experienced on most days and severity of pain, when undertaking falls-risk assessments.

To our knowledge, this study was the first study involving a large older population investigating both the risk of recurrent falls and risk of falls-related injury in association with the severity of pain in the low back and lower limb within one study. Few studies have investigated the association between one specific painful body site and recurrent falls; and even fewer studies have looked into how different pain severities in one body site are associated with recurrent falls (Stubbs, Schofield, et al., 2014; Welsh, Clarson, et al., 2019). For example, apart from the studies by Kitayuguchi et al. (2017) and Marshall et al. (2017) described earlier, Leveille et al. (2009) explored the association between falls and pain in three body sites (the back, hip and knee), but did not assess pain severity nor recurrent falls. Therefore, the present study could help to address the gap in understanding how different pain severity in two important body sites (low back and lower limb) is associated with risk of recurrent falls. General pain has been shown to increase the risk of recurrent falls by about twofold when compared with no pain (Stubbs, Binnekade, et al., 2014; Stubbs, Schofield, et al., 2014), with hip pain increasing the risk by 1.5-fold, knee pain by more than twofold, foot pain by twofold and back pain by two to threefold (Awale et al., 2017; Munch et al., 2015; Stubbs, Binnekade, et al., 2014). Gálvez-Barròn et al. (2020) showed that in those aged 65–79 years old, each unit increase in pain intensity increased the odds of recurrent falls by 47%, whereas in those aged at least 80 years, pain was not associated with recurrent falls. As the present study used mild pain as the reference group, this may explain why the amplitudes of increased recurrent falls risk are lower.

Low back pain increases the risk of falls due to its contribution to muscle weakness and decline in physical function, impaired neuromuscular function and motor control, leading to balance impairment and mobility limitation, poor daily function, poorer mental health status, diabetes cognitive impairment secondary to pain, and fear of falling. These occur even in the absence of musculoskeletal disease or radiographic evidence of arthritis (Blyth & Noguchi, 2017; Cai et al., 2020; Finlayson & Peterson, 2010; Levinger et al., 2012). Previous studies have found that falls in those experiencing pain were associated with emotional factors, depressive symptoms and cognition, while falls in those free from pain were associated with muscle weakness and muscle mass (Hirase et al., 2020). As a result, a unique aspect of this study is the use of a generally healthy cohort of community-dwelling individuals, and being able to adjust for depression and to minimize the confounding effect of cognitive impairment when evaluating the association between pain and recurrent falls.

Lower limb pain increases the risk of falls due to deficits in neuromuscular functioning, contributing to muscle weakness, mobility limitation, and reduction in proprioception and reaction time (Levinger et al., 2012). Foot pain is associated with an increased risk of falling due to reduced walking speed and step length (Benvenuti et al., 1995; Leveille et al., 1998; Menz, 2016), poorer balance and gait (Chen et al., 2003; Menz, 2016; Menz et al., 2013). Knee and hip pain are independent risk factors of falls (Doré et al., 2015; Leveille et al., 2009; Munch et al., 2015; Nahit et al., 1998), where knee pain can increase the risk of falling via its impact on balance and strength (Hicks et al., 2020). It is a unique aspect of this study to include all entities of the lower extremity to assess the overall impact of pain in the lower limb, since previous studies often included only one or two parts of the lower limb (such as the foot or the knee) (Awale et al., 2017; Hicks et al., 2020; Menz et al., 2013; Nahit et al., 1998; Stubbs, Binnekade, et al., 2014).

In the present study, among participants reporting severe pain in the low back or lower limbs, the likelihood of falling at least twice was slightly higher in males compared to females. This finding is consistent with published literature suggesting that general pain in males has a greater impact on falls risk than in females (Ek et al., 2019; Gale et al., 2018; Welmer et al., 2017), where the present study adds to the evidence by investigating low back or lower limb pain separately, confirming that the previously observed pattern in gender differences remains applicable to low back or lower limb individually. The present study found that although females more frequently reported pain, the risk of recurrent falls was not necessarily higher in females. The findings may be explained by females becoming less active and using more mobility aids in response to pain, thereby reducing their risk of falling (Gale et al., 2018; Gell et al., 2015; Welmer et al., 2017). An alternative explanation for the difference in falls risk may be that in males, pain more significantly impairs physical function and leads to more pronounced decline in muscle strength (Ek et al., 2019). Future research is needed to confirm the reasons for these findings.

In the present study, the increased likelihood of falling at least twice did not uniformly translate into an increased likelihood of falls-related injuries. Only female recurrent fallers with severe low back, or severe lower limb pain had an increased likelihood of a falls-related injury, and no association was found in the male group. However, sensitivity analyses introduced an element of doubt in the strength of the relationship between severity of low back pain experienced on most days with falls-related injury in the last 12 months (in those reporting ≥2 falls). These findings add to the conflicting results of the limited existing literature with a statistically significant association in the original analyses; further exploration and confirmation via future analyses utilizing larger datasets would be required. Previous research has shown conflicting results with respect to this (Cai et al., 2020; Leveille et al., 2009; Munch et al., 2015; Welmer et al., 2017). Munch et al. (2015) found that an increased risk of falls did not translate into an increased risk of fractures; and Cai et al. (2020) found that general pain severity could not predict injurious falls independently, but when stratified by gender, moderate and severe pain was associated with an increased risk. In contrast, other studies have shown that pain is associated with an increased risk of injurious falls (Leveille et al., 2009; Pieretti et al., 2016; Welmer et al., 2017). Compared to this study, we focused on different severity of low back pain or lower limb pain rather than general body pain. The gender difference could be explained by females being more likely to fall because of lower levels of physical activity and body strength and more muscle weakness, compared to males (Gale et al., 2016; Stevens & Sogolow, 2005). As suggested by Cai et al. (2020), this might also be explained by more reports of severe pain among women. Furthermore, females have higher fracture rates than males due to greater menopause-related bone mineral density loss (Gale et al., 2016; Stevens &

Sogolow, 2005). Females have also reported lower pain thresholds and lower pain tolerance compared to males (Welmer et al., 2017), which could lead to reduced activity. The dose–response pattern between pain severity and injurious falls could be impacted by compensatory mechanisms used for mild pain, such as the use of walking aids or avoiding vigorous physical activity (Delbaere et al., 2004; Hicks et al., 2020). Mild pain in the low back or lower limb might be an indicator of mild and possibly reversible underlying pathology to the musculoskeletal, neurological or peripheral vascular structures (Rucker-Whitaker et al., 2004), whereas more severe pain could be an indicator of more severe underlying pathology, and therefore further affecting gait and balance via instability and stiffness (Hicks et al., 2020; Leveille et al., 2009). Although not directly comparable, in the present study the lesser degree of increased risk of falls-related injury associated with pain might be attributed to the good baseline physical health and cognition of the study population (i.e. ASPREE exclusion criteria) and the use of mild pain as the reference group. Future research should explore these gender differences further.

The present study included a large sample size, high questionnaire response rate (91%), and an older, community-dwelling cohort (aged at least 70 years), who are most at risk of falling and sustaining falls-related injuries due to their age. Other studies which had involved more than 1000 participants investigating the association between pain and falls risk were usually completed outside of Australia, carried out in the United States, the United Kingdom or Japan (Stubbs, Schofield, et al., 2014; Welsh, Clarson, et al., 2019). There was one cross-sectional study completed in Australia that included 3509 patients, however, it included much younger participants (49 years old and above) and reviewed general bodily pain only (Blyth et al., 2007). Therefore, it is a unique aspect that the present study involved an older aged population of 14,892 Australian participants and reviewed the association between falls and pain in two important body sites – the low back and lower limbs.

It is a strength that detailed ASPREE data were used in the adjusted analyses, where adjusted covariates were chosen to reflect previously published studies and to avoid overfitting and over-adjustment (Zhang, 2014). It is a unique strength of this study that the ALSOP substudy data that were analysed could be linked to the data from the main ASPREE study which collected a comprehensive range of variables. Secondly, as participants were cognitively well at baseline, good recall likely improved the reliability of the self-reported data. Although ASPREE exclusion criteria reduces the generalizability of study findings to populations outside the relatively healthy, independently living, older cohort, this study would help to highlight potential intervention targets and area of focus, to optimize the functional status, mental health, quality of life and most importantly, independence of older community-dwelling people, since these aspects are closely related to pain as well as injuries from falls (Blyth & Noguchi, 2017; Cai et al., 2020; Leveille et al., 2005, 2009).

It is a limitation that self-reported data are subject to recall and response bias (Freiberger & de Vreede, 2011). A previous study concluded that recall of any fall in the last 12 months is relatively specific (91%–95%) but less sensitive (80%–89%) than prospective falls (Ganz et al., 2005), with the potential to underestimate fall frequency compared with use of diaries (Cummings et al., 1988). However, the use of 12 months as a timeframe (as stipulated in the baseline ALSOP Medical Health Questionnaire) was an appropriate choice, given its relatively higher reliability (Freiberger & de Vreede, 2011). Volunteer bias was unavoidable in the present study. The present study analysed cross-sectional data, therefore causality cannot be ascertained, and it is possible that the reported pain was a consequence of, rather than a cause of falls. However, sensitivity analyses, which excluded participants that reported a falls-related injury within the same time frame, supported study findings. Additionally, the severity of pain reported was not specific to one location only. The frequency of analgesic use was adjusted for, as analgesic use may be associated with an increased risk of falling (Leipzig et al., 1999), however, type of analgesic used was not analysed as it was not the focus of the present study. Future research should explore the impact of specific analgesic types on falls-related outcomes, as different analgesics can influence falls-risk differently (Gilmartin-Thomas et al., 2019; Leipzig et al., 1999). It is a statistical limitation that data were categorized, as information can be lost in this process. Future analyses could undertake a more in-depth exploration of recurrent fallers, to investigate if differences exist in study outcomes between those who fall 2, 3 or 4 or more times. Although the current population consisted of physically well participants (due to ASPREE exclusion criteria), less debilitating comorbidities (such as hypertension and diabetes) might have some influence in the results (Stubbs, Binnekade, et al., 2014). The underlying pathological processes associated with the low back or lower limb pain was not known and therefore not adjusted for, despite its potential to contribute to a significant portion of the impact on mobility, independent to the level of pain it caused. For example, arthritis that affects joint structures, peripheral neuropathy that affects proprioception and sensation, and myositis that causes muscle weakness. Although pain alone could cause an increased risk of falls (Foley et al. 2006), future research should explore the pathology contributing to the reported pain. Future longitudinal studies should investigate the causes and chronicity of low back or lower limb pain, and relationship between analgesic use, pain severity and risk of falls.

5 | CONCLUSION

Severe low back pain, or severe lower limb pain is associated with an increased likelihood of recurrent falls in older males and females, and an increased likelihood of falls-related injuries in older female recurrent fallers. This study analysed how different severity of pain in the low back or lower limb was associated with recurrent falls and falls-related injury for males and females, which had not been completed within a single study previously. Assessment and management of severe low back and severe lower limb pain should be prioritized when undertaking falls-risk assessment and prevention. Future longitudinal studies should further interrogate this relationship and its underlying mechanisms.

AUTHOR CONTRIBUTIONS

AT, SW, JM, AB, FC, BF, SMH, AO, YW, RW and JG-T made substantial contributions to conception and design, and/or acquisition of data, and/or analysis and interpretation of data; AT, SW, JM, AB, FC, BF, SMH, AO, YW, RW and JG-T drafted the article and/or revised it critically for important intellectual content; and AT, SW, JM, AB, FC, BF, SMH, AO, YW, RW and JG-T gave final approval of the version to be published. All authors discussed the results and commented on the manuscript.

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CONFLICT OF INTEREST

None declared.

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REFERENCES

Ambrose, A. F., Paul, G., & Hausdorff, J. M. (2013). Risk factors for falls among older adults: A review of the literature. *Maturitas*, *75*(1), 51–61.

ASPREE Investigator Group. (2013). Study design of ASPirin in reducing events in the elderly (ASPREE): A randomized, controlled trial. *Contemporary Clinical Trials*, *36*(2), 555–564.

Australian & New Zealand Falls Prevention Society. Info about falls. 2020 [updated 15 May 2021]. Retrieved from http://www.anzfallsprevention.org/info/

Awale, A., Hagedorn, T., Dufour, A., Menz, H., Casey, V., & Hannan, M. (2017). Foot function, foot pain, and falls in older adults: The Framingham Foot Study. *Gerontology*, *63*(4), 318–324.

Baron, E. C., Davies, T., & Lund, C. (2017). Validation of the 10-item Centre for Epidemiological Studies Depression Scale (CES-D-10) in Zulu, Xhosa and Afrikaans populations in South Africa. *BMC Psychiatry*, *17*(1), 6.

Bartley, E., & Fillingim, R. (2013). Sex differences in pain: A brief review of clinical and experimental findings. *British Journal of Anaesthesia*, *111*(1), 52–58.

Benvenuti, F., Ferrucci, L., Guralnik, J. M., Gangemi, S., & Baroni, A. (1995). Foot pain and disability in older persons: An epidemiologic survey. *Journal of the American Geriatrics Society*, *43*(5), 479–484.

Bland, R. C., & Newman, S. C. (2001). Mild dementia or cognitive impairment: The Modified Mini-Mental State examination (3MS) as a screen for dementia. *Canadian Journal of Psychiatry Revue Canadienne de Psychiatrie*, *46*(6), 506–510.

Blyth, F., Cumming, R., Mitchell, P., & Wang, J. (2007). Pain and falls in older people. *European Journal of Pain (London, England)*, *11*(15), 564–571.

Blyth, F., & Noguchi, N. (2017). Chronic musculoskeletal pain and its impact on older people. *Best Practice & Research Clinical Rheumatology*, *31*(2), 160–168.

Boonstra, A. M., Stewart, R. E., Köke, A. J., Oosterwijk, R. F., Swaan, J. L., Schreurs, K. M., & Schiphorst Preuper, H. R. (2016). Cut-off points for mild, moderate, and severe pain on the numeric rating scale for pain in patients with chronic musculoskeletal pain: Variability and influence of sex and catastrophizing. *Frontiers in Psychology*, *7*, 1466.

Breivik, H., Borchgrevink, P. C., Allen, S. M., Rosseland, L. A., Romundstad, L., Hals, E. K., Kvarstein, G., & Stubhaug, A. (2008). Assessment of pain. *British Journal of Anaesthesia*, *101*(1), 17–24.

Brenton-Rule, A., Dalbeth, N., Menz, H. B., Bassett, S., & Rome, K. (2016). Foot and ankle characteristics associated with falls in adults with established rheumatoid arthritis: A cross-sectional study. *BMC Musculoskeletal Disorders*, *17*, 22.

Cai Y, Leveille SG, Shi L, Chen P, You T. Chronic pain and risk of injurious falls in community-dwelling older adults. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences* [Internet]. 2020, *76*, e179, e186.

Cameron, A., & Trivedi, P. (2009). *Microeconometrics using stata*. Stata Press.

Carter, R., Lipsitz, S., & Tilley, C. (2005). Quasi-likelihood estimation for relative risk regression models. *Biostatistics (Oxford, England)*, *6*(1), 39–44.

Cederbom, S., & Arkkukangas, M. (2019). Impact of the fall prevention Otago Exercise Programme on pain among community-dwelling older adults: A short- and long-term follow-up study. *Clinical Interventions in Aging*, *14*, 721–726.

Chen, J., Devine, A., Dick, I. M., Dhaliwal, S. S., & Prince, R. L. (2003). Prevalence of lower extremity pain and its association with functionality and quality of life in elderly women in Australia. *The Journal of Rheumatology*, *30*(12), 2689–2693.

Chen, W., Qian, L., Shi, J., & Franklin, M. (2018). Comparing performance between log-binomial and robust Poisson regression models for estimating risk ratios under model misspecification. *BMC Medical Research Methodology*, *18*, 63.

Crowe, M., Jordan, J., Gillon, D., McCall, C., Frampton, C., & Jamieson, H. (2017). The prevalence of pain and its relationship to falls, fatigue, and depression in a cohort of older people living in the community. *Journal of Advanced Nursing*, *73*(11), 2642–2651.

Cummings, P. (2009). The relative merits of risk ratios and odds ratios. *Archives of Pediatrics & Adolescent Medicine*, *163*(5), 438–445.

Cummings, S. R., Nevitt, M. C., & Kidd, S. (1988). Forgetting falls. The limited accuracy of recall of falls in the elderly. *Journal of the American Geriatrics Society*, *36*(7), 613–616.

Dai, W., Tham, Y. C., Chee, M. L., Tan, N. Y. Q., Wong, K. H., Majithia, S., Sabanayagam, C., Lamoureux, E., Wong, T. Y., & Cheng, C. Y. (2018). Falls and recurrent falls among adults in a multi-ethnic Asian population: The Singapore Epidemiology of Eye Diseases Study. *Scientific Reports*, *8*(7), 7575.

Daut, R. L., Cleeland, C. S., & Flanery, R. C. (1983). Development of the Wisconsin brief pain questionnaire to assess pain in cancer and other diseases. *Pain*, *17*(2), 197–210.

Deandrea, S., Lucenteforte, E., Bravi, F., Foschi, R., La Vecchia, C., & Negri, E. (2010). Risk factors for falls in community-dwelling older people: A systematic review and meta-analysis. *Epidemiology*, *21*(5), 658–668.

Delbaere, K., Crombez, G., Vanderstraeten, G., Willems, T., & Cambier, D. (2004). Fear-related avoidance of activities, falls and physical frailty. A prospective community-based cohort study. *Age and Ageing*, *33*(4), 368–373.

Doré, A. L., Golightly, Y. M., Mercer, V. S., Shi, X. A., Renner, J. B., Jordan, J. M., & Nelson, A. E. (2015). Lower-extremity osteoarthritis and the risk of falls in a community-based longitudinal study of adults with and without osteoarthritis. *Arthritis Care & Research*, *67*(5), 633–639.

Edeer, A. O., & Tuna, H. (2012). Management of chronic musculoskeletal pain in the elderly: Dilemmas and remedies. In *Pain in Perspective [Internet]*. InTechOpen. https://doi.org/10.5772/50780

Ek, S., Rizzuto, D., Fratiglioni, L., Calderón-Larrañaga, A., Johnell, K., Sjöberg, L., Xu, W., & Welmer, A. K. (2019). Risk factors for injurious falls in older adults: The role of sex and length of follow-up. *Journal of the American Geriatrics Society*, *67*(2), 246–253.

Finlayson, M. L., & Peterson, E. W. (2010). Falls, aging and disability. *Physical Medicine and Rehabilitation Clinics of North America*, *21*(2), 357–373.

Foley, S. J., Lord, S. R., Srikanth, V., Cooley, H., & Jones, G. (2006). Falls risk is associated with pain and dysfunction but not radiographic osteoarthritis in older adults: Tasmanian Older Adult Cohort study. *Osteoarthritis and Cartilage*, *14*(6), 533–539.

Freiberger, E., & de Vreede, P. (2011). Falls recall—Limitations of the most used inclusion criteria. *European Review of Aging and Physical Activity*, *8*, 105–108.

Gale, C. R., Cooper, C., & Aihie, S. A. (2016). Prevalence and risk factors for falls in older men and women: The English Longitudinal Study of Ageing. *Age and Ageing*, *45*(6), 789–794.

Gale, C. R., Westbury, L. D., Cooper, C., & Dennison, E. M. (2018). Risk factors for incident falls in older men and women: The English longitudinal study of ageing. *BMC Geriatrics*, *18*(1), 117.

Gálvez-Barrón, C., Formiga, F., Miñarro, A., Macho, O., Narvaiza, L., Dapena, M. D., Pujol, R., & Rodríguez-Molinero, A. (2020). Pain and recurrent falls in the older and oldest-old non-institutionalized population. *BMC Geriatrics*, *20*(1), 15.

Ganz, D. A., Higashi, T., & Rubenstein, L. Z. (2005). Monitoring falls in cohort studies of community-dwelling older people: Effect of the recall interval. *Journal of the American Geriatrics Society*, *53*(12), 2190–2194.

Gell, N. M., Wallace, R. B., LaCroix, A. Z., Mroz, T. M., & Patel, K. V. (2015). Mobility device use in older adults and incidence of falls and worry about falling: Findings from the 2011-2012 national health and aging trends study. *Journal of the American Geriatrics Society*, *63*(5), 853–859.

Gilmartin-Thomas, J. F., Bell, J. S., Liew, D., Arnold, C. A., Buchbinder, R., Chapman, C., Cicuttini, F., Dobbin, M., Gibson, S. J., Giummarra, M. J., Gowan, J., Katz, B., Lubman, D. I., McCrone, M., Pilgrim, J., Synnot, A., van Dyk, E., Workman, B., & McNeil, J. (2019). Chronic pain medication management of older populations: Key points from a national conference and innovative opportunities for pharmacy practice. *Research in Social & Administrative Pharmacy*, *15*(2), 207–213.

Gilmartin-Thomas, J. F., Cicuttini, F. M., Owen, A. J., Wolfe, R., Ernst, M. E., Nelson, M. R., Lockery, J., Woods, R. L., Britt, C., Liew, D., Murray, A., Workman, B., Ward, S. A., McNeil, J. J., & ASPREE Investigator Group (2020). Moderate or severe low back pain is associated with body mass index amongst community-dwelling older Australians. *Archives of Gerontology and Geriatrics*, *91*, 104231.

Gilmartin-Thomas, J. F., Ernst, M. E., Nelson, M. R., Lockery, J., Ward, S., Woods, R., Britt, C., Murray, A., Workman, B., McNeil, J., & ASPREE Investigators. (2020). Musculoskeletal pain experienced on most days is a common accompaniment of ageing amongst community-dwelling older Australians: A questionnaire-based study. *Journal of Aging and Health.*, *33*(1–2), 39–47.

Gutiérrez Lombana, W., & Gutiérrez Vidál, S. E. (2012). Pain and gender differences. A clinical approach. *Colombian Journal of Anestesiology*, *40*(3), 207–212.

Hartvigsen, J., Hancock, M. J., Kongsted, A., Louw, Q., Ferreira, M. L., Genevay, S., Hoy, D., Karppinen, J., Pransky, G., Sieper, J., Smeets, R. J., Underwood, M., & Lancet Low Back Pain Series Working Group. (2018). What low back pain is and why we need to pay attention. *Lancet*, *391*(10137), 2356–2367.

Hicks, C., Levinger, P., Menant, J. C., Lord, S. R., Sachdev, P. S., Brodaty, H., & Sturnieks, D. L. (2020). Reduced strength, poor balance and concern about falls mediate the relationship between knee pain and fall risk in older people. *BMC Geriatrics*, *20*(1), 94.

Hirase, T., Makizako, H., Okubo, Y., Lord, S. R., Okita, M., Nakai, Y., Takenaka, T., Kubozono, T., & Ohishi, M. (2020). Falls in community-dwelling older adults with lower back or knee pain are associated with cognitive and emotional factors. *International Journal of Environmental Research and Public Health*, *17*(14), 4960.

Hjermstad, M. J., Fayers, P. M., Haugen, D. F., Caraceni, A., Hanks, G. W., Loge, J. H., Fainsinger, R., Aass, N., Kaasa, S., & European Palliative Care Research Collaborative (EPCRC). (2011). Studies comparing numerical rating scales, verbal rating scales, and visual analogue scales for assessment of pain intensity in adults: A systematic literature review. *Journal of Pain and Symptom Management*, *41*(6), 1073–1093.

Jehu, D. A., Davis, J. C., & Liu-Ambrose, T. (2020). Risk factors for recurrent falls in older adults: A study protocol for a systematic review with meta-analysis. *BMJ Open*, *10*(5), e033602.

Kitayuguchi, J., Kamada, M., Inoue, S., Kamioka, H., Abe, T., Okada, S., & Mutoh, Y. (2017). Association of low back and knee pain with falls in Japanese community-dwelling older adults: A 3-year prospective cohort study. *Geriatrics & Gerontology International*, *17*(6), 875–884.

Lamoth, C. J., Meijer, O. G., Daffertshofer, A., Wuisman, P. I., & Beek, P. J. (2006). Effects of chronic low back pain on trunk coordination and back muscle activity during walking: Changes in motor contro. *European Spine Journal*, *15*(1), 23–40.

Lee, S., Oh, E., & Hong, G. S. (2018). Comparison of factors associated with fear of falling between older adults with and without a fall history. *International Journal of Environmental Research and Public Health*, *15*(5), 982.

Leipzig, R. M., Cumming, R. G., & Tinetti, M. E. (1999). Drugs and falls in older people: A systematic review and meta-analysis: I. Psychotropic drugs. *Journal of the American Geriatrics Society*, *47*(1), 30–39.

Leveille, S. G., Guralnik, J. M., Ferrucci, L., Hirsch, R., Simonsick, E., & Hochberg, M. C. (1998). Foot pain and disability in older women. *American Journal of Epidemiology*, *148*(7), 657–665.

Leveille, S. G., Jones, R. N., Kiely, D. K., Hausdorff, J. M., Shmerling, R. H., Guralnik, J. M., Kiel, D. P., Lipsitz, L. A., & Bean, J. F. (2009). Chronic musculoskeletal pain and the occurrence of falls in an older population. *Journal of the American Medical Association*, *302*(20), 2214–2221.

Leveille, S. G., Zhang, Y., McMullen, W., Kelly-Hayes, M., & Felson, D. T. (2005). Sex differences in musculoskeletal pain in older adults. *Pain*, *116*(3), 332–338.

Levinger, P., Wallman, S., & Hill, K. (2012). Balance dysfunction and falls in people with lower limb arthritis: Factors contributing to risk and effectiveness of exercise interventions. *European Review of Aging and Physical Activity*, *9*, 17–25.

Marshall, L. M., Litwack-Harrison, S., Makris, U. E., Kado, D. M., Cawthon, P. M., Deyo, R. A., Carlson, N. L., Nevitt, M. C., & Osteoporotic Fractures in Men Study (MrOS) Research Group. (2017). A prospective study of back pain and risk of falls among older community-dwelling men. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences*, *72*(9), 1264–1269.

McNeil, J. J., Woods, R. L., Nelson, M. R., Reid, C. M., Kirpach, B., Wolfe, R., Storey, E., Shah, R. C., Lockery, J. E., Tonkin, A. M., Newman, A. B., Williamson, J. D., Margolis, K. L., Ernst, M. E., Abhayaratna, W. P., Stocks, N., Fitzgerald, S. M., Orchard, S. G., Trevaks, R. E., … ASPREE Investigator Group. (2018). Effect of aspirin on disability-free survival in the healthy elderly. *New England Journal of Medicine*, *379*(16), 1499–1508.

McNeil, J. J., Woods, R. L., Ward, S. A., Britt, C. J., Lockery, J. E., Beilin, L. J., & Owen, A. J. (2019). Cohort profile: The ASPREE longitudinal study of older persons (ALSOP). *International Journal of Epidemiology*, *48*(4), 1048–1049.

Menz, H. B. (2016). Chronic foot pain in older people. *Maturitas*, *91*, 110–114.

Menz, H. B., Dufour, A. B., Casey, V. A., Riskowski, J. L., McLean, R. R., Katz, P., & Hannan, M. T. (2013). Foot pain and mobility limitations in older adults: The Framingham Foot Study. *The Journals of Gerontology Series A, Biological Sciences and Medical Sciences*, *68*(10), 1281–1285.

Munch, T., Harrison, S. L., Barrett-Connor, E., Lane, N. E., Nevitt, M. C., Schousboe, J. T., Stefanick, M., & Cawthon, P. M. (2015). Pain and falls and fractures in community-dwelling older men. *Age and Ageing*, *44*(6), 973–979.

Nahit, E. S., Silman, A. J., & Macfarlane, G. J. (1998). The occurrence of falls among patients with a new episode of hip pain. *Annals of the Rheumatic Diseases*, *57*(3), 166–168.

Patel, K. V., Phelan, E. A., Leveille, S. G., Lamb, S. E., Missikpode, C., Wallace, R. B., Guralnik, J. M., & Turk, D. C. (2014). High prevalence of falls, fear of falling, and impaired balance in older adults with pain in the United States: Findings from the 2011 National Health and Aging Trends Study. *Journal of the American Geriatrics Society*, *62*(10), 1844–1852.

Pieretti, S., Di Giannuario, A., Di Giovannandrea, R., Marzoli, F., Piccaro, G., Minosi, P., & Aloisi, A. M. (2016). Gender differences in pain and its relief. *Annali dell'Istituto Superiore di Sanita*, *52*(2), 184–189.

Radloff, L. S. (1977). The CES-D scale: A self report depression scale for research in the general population. *Applied Psychological Measurement*, *1*, 385–401.

Rao, S. (2005). Prevention of falls in older patients. *American Family Physician*, *72*(1), 81–88.

Rucker-Whitaker, C., Greenland, P., Liu, K., Chan, C., Guralnik, J. M., Criqui, M. H., Taylor, L., Pearce, W. H., & McGraeMcDermott, M. (2004). Peripheral arterial disease in African Americans: Clinical characteristics, leg symptoms, and lower extremity functioning. *Journal of the American Geriatrics Society*, *52*(6), 922–930.

Sroka, C., & Nagaraja, H. (2018). Odds ratios from logistic, geometric, Poisson, and negative binomial regression models. *BMC Medical Research Methodology*, *18*, 112.

Stevens, J. A., & Sogolow, E. D. (2005). Gender differences for non-fatal unintentional fall related injuries among older adults. *Injury Prevention*, *11*(2), 115–119.

Stubbs, B., Binnekade, T., Eggermont, L., Sepehry, A. A., Patchay, S., & Schofield, P. (2014). Pain and the risk for falls in community-dwelling older adults: Systematic review and meta-analysis. *Archives of Physical Medicine and Rehabilitation*, *95*(1), 175–187.

Stubbs, B., Eggermont, L., Patchay, S., & Schofield, P. (2015). Older adults with chronic musculoskeletal pain are at increased risk of recurrent falls and the brief pain inventory could help identify those most at risk. *Geriatrics & Gerontology International*, *15*(7), 881–888.

Stubbs, B., Schofield, P., Binnekade, T., Patchay, S., Sepehry, A., & Eggermont, L. (2014). Pain is associated with recurrent falls in community-dwelling older adults: Evidence from a systematic review and meta-analysis. *Pain Medicine*, *15*(7), 1115–1128.

Valderrama-Hinds, L. M., Al Snih, S., Chen, N. W., Rodriguez, M. A., & Wong, R. (2018). Falls in Mexican older adults aged 60 years and older. *Aging Clinical and Experimental Research*, *30*(11), 1345–1351.

Waldron, N., Hill, A., & Barker, A. (2012). Falls prevention in older adults – Assessment and management. *Australian Family Physician*, *14*(12), 930–935.

Welmer, A. K., Rizzuto, D., Calderón-Larrañaga, A., & Johnell, K. (2017). sex differences in the association between pain and injurious falls in older adults: A population-based longitudinal study. *American Journal of Epidemiology*, *186*(9), 1049–1056.

Welsh, V. K., Clarson, L. E., Mallen, C. D., & McBeth, J. (2019). Multisite pain and self-reported falls in older people: Systematic review and meta-analysis. *Arthritis Research & Therapy*, *21*(1), 67.

Welsh, V. K., Mallen, C. D., Ogollah, R., Wilkie, R., & McBeth, J. (2019). Investigating multisite pain as a predictor of self-reported falls and falls requiring health care use in an older population: A prospective cohort study. *PLoS One*, *14*(12), e0226268.

Wong, A. Y., Karppinen, J., & Samartzis, D. (2017). Low back pain in older adults: Risk factors, management options and future directions. *Scoliosis and Spinal Disorders*, *12*(14), 14.

World Health Organization. Obesity and overweight. 2020 [updated 2020]. Retrieved from: https://www.who.int/news-room/fact-sheets/detail/obesity-and-overweight/.

World Health Organization. Falls 2021 [updated April 26, 2021]. Retrieved from http://who.int/news-room/fact-sheets/detail/falls

Zhang, Z. (2014). Too much covariates in a multivariable model may cause the problem of overfitting. *Journal of Thoracic Disease*, *6*(9), E196–E197.

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