Accepted Manuscript

Pain and the risk for falls in community dwelling older adults: A systematic review and Meta-analysis

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PII: S0003-9993(13)00892-7

DOI: 10.1016/j.apmr.2013.08.241

Reference: YAPMR 55575

To appear in: *ARCHIVES OF PHYSICAL MEDICINE AND REHABILITATION*

Received Date: 7 May 2013

Revised Date: 14 August 2013

Accepted Date: 24 August 2013

Please cite this article as: Stubbs B, Eggermont L, Binnekade T, Sephery A, Patchay S, Schofield SP, Pain and the risk for falls in community dwelling older adults: A systematic review and Meta-analysis, *ARCHIVES OF PHYSICAL MEDICINE AND REHABILITATION* (2013), doi: 10.1016/j.apmr.2013.08.241.

Word count: 4990

Archives of Physical Medicine and Rehabilitation

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Running title: Falls in older adults with chronic pain

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Conflict of Interest

None to declare by any author

Acknowledgements

We would like to thank the authors who kindly provided additional data for the meta-analysis, including Prof Suzanne Leveille, Dr Daina Sturnieks, Dr M Kwan and Professor SR Lord, Dr Jason Leung, Dr Yagci, Dr Bekibele.

Pain and the risk for falls in community dwelling older adults: A systematic review and Meta-analysis

Abstract

Objective

To conduct a systematic review and meta-analysis to establish the association between pain and falls in community dwelling older adults.

Data Sources

Electronic databases from inception until 1st March 2013 including Cochrane Library, CINAHL, EBSCO, EMBASE, PubMed and PsycINFO.

Study Selection

Two reviewers independently conducted the searches and completed methodological assessment of all included studies. Studies were included that (a) focussed on older adults over 60 years old, (b) recorded falls over 6 or more months, (c) identified a group with and without pain. Studies were excluded that (d) included participants with dementia, a neurological condition (e.g. stroke), (e) participants whose pain was caused by a previous fall, (f) individuals with surgery/ fractures in the past 6 months.

Data extraction

One author extracted all data and this was independently validated by another author.

Data synthesis

1,334 articles were screened and 21 studies met the eligibility criteria. 50.5% of older adults with pain reported one or more fall over 12 months compared to 25.7% of controls ($p<0.001$). A global meta-analysis with 14 studies (n=17,926) demonstrated that pain was associated with an increased odds of falling (OR: 1.56, 95% Confidence Interval (CI): 1.36 to 1.79, I^2=53%). A subgroup meta-analysis incorporating studies that monitored falls prospectively established that the odds of falling was significantly higher in those with pain (n=4,674; OR: 1.71, CI: 1.48 to 1.98, I^2=0%). Foot pain was strongly associated with falls (n=691; OR: 2.38, CI: 1.62 to 3.48, I^2=8%) as was chronic pain (n= 5,367; OR 1.80, CI: 1.56 to 2.09, I^2=0%).

Conclusion

Community dwelling older adults with pain were more likely to have fallen in the past 12 months and fall again in the future. Foot and chronic pain were particularly strong risk factors for falls and clinicians should routinely enquire about these when completing falls risk assessments.

Key words: falls, older adults, risk factors, systematic review, pain, elderly

Abbreviations

PRISMA - Preferred Reporting Items for Systematic Reviews and Meta-analysis statement

OR – odds ratio

RaR - rate ratio

CI – Confidence interval (all reported at 95%)

NOS – Newcastle Ottawa Scale

RCT - randomised controlled trials

Falls are a leading cause of unintentional injury and death in older age [1-2] and can also result in impaired mobility, disability, fear of falling and reduced quality of life [3-6]. In addition, falls are very costly to health and social care systems [7]. Unsurprisingly, the prevention of falls in older adults is a public health priority in many countries across the world [8-10]. A key component in preventing falls is the identification of important factors that may increase the risk of falls [4, 9, 11]. However, the 'gold standard' multifactorial interventions to reduce falls have had relatively limited success [11], which may be because some important risk factors remain elusive [6]. One important and potentially significant risk factor that appears to be continually overlooked is pain [6, 12-13]. For example, the American and British Geriatric Societies [14] provide detailed guidance on the assessment of individuals at risk of falls but there is no specific mention of the assessment of pain or its importance as a falls risk factor. This is surprising for a number of reasons. Firstly, pain is associated with mobility deficits, impaired gait and balance deficits, all of which are well established internal risk factors for falls [4, 6, 12, 15-16]. Secondly, pain is very common in older people, with. up to 76% of older people in the community experiencing it [17].

It is likely that pain has not been identified as a risk factor for falls due to the relative dearth of research specifically investigating the association of pain and falls in older people [6]. Whilst there has been comparatively few authors primarily investigating this, in 1999 Arden and colleagues [18] demonstrated that the presence of severe chronic knee pain was associated with a 50% increased risk of multiple falls. More recently, Leveille and colleagues [6] also established that chronic pain was associated with a significantly increased risk of falls. A recent review [2] investigated 31 common risk factors for falls in community dwelling older adults did provide some consideration of the influence of pain with falls. The authors established that pain (yes/ no) was associated with an increased risk of single falls (2 studies; OR 1.39 (CI 95%: 1.14 to 1.62) and multiple falls (6 studies; OR 1.60 (CI 95%: 1.44 to 1.78). However, the results were overshadowed by a focus on other risk factors. Whilst this review provides a useful insight, its generic focus means that it was not able to provide a detailed exploration of the association of pain and falls and this is warranted.

Studies that explore the association between pain and the risk of falling offer valuable information for clinicians working with older people. In order to address this we set out to conduct a systematic review of studies investigating the association between pain and falls. . Previous research [6, 13, 18] has suggested that certain sites and duration (e.g. chronic) of pain may heighten the risk for falls. Therefore, wherever possible we will establish details of the site, location and duration of pain and the influence of these on the risk of falls. A number of authors [4, 8, 19-20] have emphasised the importance of developing a common taxonomy when reporting falls within trials to enable replication and comparison. In order to address this, we will also establish current definitions employed and methods of ascertaining falls within the literature. The primary aim of this systematic review and meta-analysis is to establish if pain is associated with increased odds of falling in community dwelling older people.

Methods

The study is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-analysis statement (PRIMSA) [21].

Eligibility criteria

Studies were considered for inclusion if they (a) focussed on community dwelling older adults with a mean age > 60 years, (b) recorded falls as an outcome, including single and multiple falls, (c) falls were ascertained over 6 months or more through either a prospective or retrospective suitable method (e.g. self-report questionnaire or interview, falls calendars, postcards, telephone interviews). (d) The sample included: older adults that were identified as having pain and older adults without pain. We accepted the assessment of pain through any method, including validated outcome measures, clinical diagnosis and self-report measures. Papers were excluded if they: (e) included participants with dementia, due to the difficulty obtaining the accurate ascertainment of falls and the increased risk of falls seen in this population [22]. (f) Reported on a sample whose pain was identified as being caused by a previous fall in order to reduce the likelihood of reverse causality. (g) Reported on falls in any neurological condition (e.g. stroke, multiple sclerosis) in an attempt to reduce the influence of comorbidity on falls risk [23] or (h) included participants with a recent history of trauma (any fractures within the last 6 months) or orthopaedic surgery (in the last 6 months). The type and design of the studies considered for inclusion were not limited, but reviews, expert opinions and PhD theses were excluded. We only considered studies that were written in English.

Information Sources

A systematic review of the literature was conducted according to the general guidance provided by Cochrane reviewer's handbook [24]. Major electronic databases were searched from inception until 1st March 2013, including the Cochrane Library, CINAHL, EBSCO, EMBASE, PubMed and PsycINFO. Online searches of key journals were conducted including the 'in press' sections of the Journal of the American Geriatrics Society, Archives of Physical Medicine and Rehabilitation and Age and Ageing. In addition the reference lists of relevant recent systematic reviews were also reviewed.

Systematic Search Strategy

The search terms used were categorised in population (older adults, aged, elderly, old age, frail) condition (pain*, chronic pain, persistent pain, musculoskeletal pain) and outcome (fall*, accidental falls). (See Supplemental Appendix 1., available online.) Key authors were contacted to establish if any key studies were missed or currently being undertaken that warranted inclusion. In addition, we contacted primary authors up to three times if additional clarification/ information were required to determine if an article was eligible.

Study Selection

Two reviewers independently (BS/TB) conducted the search strategy, screening article titles, key words and abstracts to assess for eligibility. Articles that met the eligibility criteria were considered in a full text review by the same independent reviewers (BS/TB) and a final list of included articles was established by consensus. A third reviewer was utilised for mediation (LE). If studies reported on the same data in different publications, we utilised the data from the largest and/ or most recent sample.

Data Collection

Data extraction was initially conducted by one reviewer (BS) and independently validated by a second reviewer (TB). The data extracted from each article included: year of publication, design, sample size, participant information (age, % females, comorbidity), method of pain assessment, location/duration/severity of pain, fall definition, method of falls ascertainment and number of fallers (one or more falls in a set time period) in the pain and control samples. Wherever possible we also extracted any reported association statistics (e.g. odds ratio (OR), rate ratio (RaR) etc.) investigating the relationship between pain and falls together with 95% confidence interval (CI), standard error and *p* value. If association statistics were not available, we extracted the raw data and calculated the unadjusted odds ratio with a 2 X 2 table (together with a 95% CI and p value for each analysis). These results will be hereafter described as 'unadjusted odd ratios based on raw data'.

Methodological and Risk of Bias Assessment

Two reviewers (BS/TB) independently completed the methodological assessment of included articles using the Newcastle Ottawa Scale (NOS) [25]. The NOS provides an assessment of the quality of non-randomised controlled trials and its content validity and reliability have been established [25]. Included studies are judged across three key areas: selection, comparability and outcomes. The NOS provides an overall score for methodological quality of up to 9 stars and scores of 5 and above are considered of satisfactory quality [26]. The NOS provides pre-defined scoring criteria, but can be further specified for the topic of study. We adapted the NOS to provide one star accounting for age and another for gender or comorbidity when considering the comparability of included studies. In addition, we updated the requirements for a star when considering the ascertainment of falls in the exposure category.

Summary measures

Whenever possible we extracted association statistics (together with 95% CI and *p* value) investigating the relationship between pain and falls, together with any adjusted confounding factors. In addition, we extracted the raw data from each study to establish an unadjusted OR for the association between pain and falls in a 2 X 2 table. If necessary 2 X 3 or 2 X 4 study designs were pooled to generate a 2 X 2 table. If the raw data was not available we attempted to contact the primary authors up to three times to enable inclusion in the meta-analysis.

In order to establish the annual percentage of older people with and without pain that reported one or more falls, we utilised the raw data from the 2 X 2 tables and calculate point estimate for the two groups.

Data Synthesis

Due to the variation in the reporting and adjustment for multiple confounding factors in each study, we only pooled studies when we were able to calculate the unadjusted OR from the raw data. To assess the impact of the duration of the pain, we conducted a subgroup analysis investigating the association between chronic pain (pain lasting three or more months) and non-chronic pain (pain lasting less than three months). In addition we conducted a subgroup analysis in order to determine the relationship between the location of pain and the method of ascertaining falls (prospective or retrospective) on the odds of falling. For each analysis we calculated the 95% CI and p value.

Due to the heterogeneity of the data acquired, a random effects model (DerSimonian-Laird [27]) was employed. This provides a more conservative score than a fixed effects model given that it incorporates within and between study variance [28]. To measure heterogeneity I^2 statistic was calculated and scores of 25%, 50% and 75% were considered low, moderate and high heterogeneity respectively [29]. All data synthesis was conducted with the Comprehensive Meta-Analysis (Vers. 2.0) STATA. In order to assess for publication bias, we undertook a visual inspection of a funnel plot for the studies included in the global meta-analysis and removed any outliers in a sensitivity analysis [24]. In addition, where possible we conducted a meta-regression using the mean age and gender as moderators. This provided an assessment of the influence of these factors on the observed effect seen in each analysis.

Outline of Results

The results of the narrative synthesis and meta-analysis are reported together. First, we considered the percentage of fallers over 12 months for older adults with and without pain utilising the raw data from the 2 X 2 tables. Second, we considered the results of the individual studies in the narrative synthesis and report a global meta-analysis investigating the association between pain and falls. We then undertook a subgroup analysis to establish the influence of falls ascertainment (prospective/ retrospective), location of the pain and the duration of the pain (chronic/ non chronic) on the relationship between pain and falls.

Results

Study Selection

The original electronic search produced 1334 hits and 10 additional articles were found from other sources. After the removal of duplicates, 795 abstracts were examined and 69 articles were considered in the full text review. At this stage, we contacted 13 authors requesting additional information and 4 of these were subsequently included in the review [30-33]. In total, 48 articles were excluded with reasons and 21 studies were included in the narrative review [5-6, 12-13, 18, 30-45] and 14 of these [5-6, 12, 33-36, 38, 40-42] (n=17,926) were included in the meta-analysis. The search strategy is presented in Figure 1.

Insert Figure 1 about here

Study and participant characteristics

The summary of the 21 included studies is presented in Supplemental Table 1 (available online). Seven studies had a case-control design [13, 30, 32-36] and 14 were cohort studies [5-6, 12, 18, 31, 37-45]. The sample sizes in each study varied considerably, Arden et al [37] was the largest and included 6,441 older adults with 1,427 of those reporting prevalent knee pain, whilst Levinger et al [30] was the smallest and included 62 older adults with 35 experiencing knee pain. The method of ascertaining pain and the location and duration varied considerably in each study and is summarised in Supplemental Table 1. Data on the mean age and gender for two comparative groups (either (a) the pain/ no pain group or (b) fallers/ non fallers), were only available for 13 of the included studies [6, 12-13, 30-31, 33-35, 37-38, 40-42] and is presented in Supplemental Table 1. There was considerable inconsistency and heterogeneity in the reporting of comorbidities in each study, with few studies providing clear information on this, but wherever available these are presented in Supplemental Table 1.

Definition and ascertainment of falls

Nine studies did not provide a definition for a fall [12, 18, 30, 34-38, 43]. Seven studies provided a definition for a fall referenced by the literature and the most common was that offered by the Kellogg International working group [46] (n=4) [5-6, 33, 45] and the definition offered by Tinnetti [47] (n=3) [13, 41-42] whilst a further 5 studies offered a definition, but this was not referenced by the literature [31-32, 39-40, 44] see Supplemental Table 1.

Prevalence of falls reported by older adults with and without pain

We calculated the mean percentage of fallers (one or more fall) over 12 months for the older adults with and without pain utilising the raw data from 12 studies [5, 12, 30-33, 35-36, 38 , 40-42] with the data from the 2 X 2 tables. This established that 50.5% of older adults with pain reported one or more fall over 12 months compared to 25.76% of the control group ($p<0.001$).

Association between pain and falls in the individual studies

Twelve studies reported an adjusted association statistic to quantify the relationship between pain and falls [5-6, 12-13, 18, 34, 37-39, 43-45] and each of these reported at least one positive association between pain and falls. A wide range of association statistics were used together with the adjustment of multiple confounding factors and this information is summarised in Table 1.

Insert Table 1 about here

It was possible to calculate the unadjusted OR from the raw data for 14 studies [5-6, 12, 30-36, 38, 40-42] and each is presented in Table 1. The primary author of 6 studies provided additional data for the meta-analysis [5-6, 31-33, 38]. Within the meta-analysis, we pooled the data of three studies into a 2 X 2 study design [6, 12, 33].

Meta-analysis of Overall Odds of falling

A global meta-analysis was conducted with 14 studies [5-6, 12, 30-36, 38, 40-42] (n= 17,926: 5,825 with pain and 12,101 without pain) and established that pain was associated with a 56% increased odds of falling (OR: 1.56, CI: 1.36 to 1.79, p<0.0001). The data was heterogeneous (I^2=52%, p <0.05, see Figure 2a. A visual inspection of a funnel plot established one study [32] was at risk of publication bias and was subsequently excluded from all further subgroup analysis [24] (see Figure 2b.)

Meta-analysis of falls risk according to the method of falls ascertainment

A meta-analysis with the five studies [5-6, 31, 41-42] (n=4,674) that collected falls data prospectively, established that older adults with pain had an increased odds of falling by 71% (OR: 1.71, CI: 1.48 to 1.98, p<0.0001). The data was homogenous (I^2=0% p=0.5). A subgroup analysis was conducted with nine studies [12, 30, 32-36, 38, 40] (n=13,012) that collected falls data retrospectively and this established the odds of falling was increased by 43% (OR: 1.43, CI: 1.22 to 1.69, p <0.0001). This subgroup analysis was heterogeneous (I^2=49%, p<0.05), see figure 3.

Insert figure 3 about here

Different pain locations and association with falls.

The results of studies looking at single sites of pain and the association with falls showed inconsistent results. For instance, only 2 of the 6 studies that examined falls in people with hip pain found a significantly increased risk for falls [18, 44]. Three out of six studies established that knee pain demonstrated an increased falls risk [13, 37, 40], but 1 study found that this risk was only increased in those multiple fallers [13]. Similarly, three out of five studies [13, 38, 43] demonstrated that back/ neck pain was associated with falls and two found the risk was particularly increased for multiple falls [13, 43]. Three out of four studies established that foot pain was associated with an increased risk of falls ranging from 87% and 260% [34, 42-43]. When looking at 'body pain' of an undefined location or mixed pain sites, 6 studies [5, 31-32, 38, 43, 45] out of seven demonstrated that pain was associated with an increased risk of falls. It was possible to calculate the unadjusted OR calculated for two of these studies [5, 38] and it was within 6% from that reported in the adjusted association reported in each paper. Finally, both studies [6, 12] investigating multisite/ widespread pain established an increased risk of falls. The adjusted association statistics and unadjusted OR calculated from the raw data are presented in Table 1.

Meta-analysis of falls risk according to location of pain

A subgroup meta-analysis with 3 studies [34, 41-42] (n=691) found that foot pain was associated with a 138% increased odds of falling (OR: 2.38, CI: 1.62 to 3.48, $p< 0.0001$). The data was homogeneous (I^2=8%, p=0.33). A subgroup meta-analysis with 3 studies [31, 36, 40] (n=2,786) established hip pain was associated with a 36% increased odds of falling (OR: 1.36, CI: 1.00 to 1.84, p=0.05). The data was homogenous (I^2 =0%, p=0.67). A subgroup analysis with 3 studies [30-31, 40] (n=2,634) did not establish a significant relationship between knee pain and falls whilst a subgroup analysis of 'other' types of pain with 5 studies [5-6, 12, 31, 38] (total n =6,397) established a 54% increased odds of falling (OR: 1.54, CI: 1.25 to 1.88, $p<0.0001$, I^2=58%, $p<0.05$). See Figure 4 for each meta-analysis.

Insert Figure 4 about here

Pain severity

Each of the 3 studies [6, 33, 39] that investigated the relationship between pain severity and falls established that the risk of falls was higher as pain severity and its interference with activities increased.

Chronic Pain

All of the seven studies included [6, 18, 38, 13, 43, 31-32] established that chronic pain was associated with an increased risk of falls although this was only true for recurrent fallers in three of these [13, 18, 43].

Meta-analysis of falls risk according to the duration of pain

A subgroup meta-analysis with 3 studies [6, 31, 38] (n=5,367) established the odds of falling was increased by 80% with chronic pain (OR 1.80, CI: 1.56 to 2.09, *p*<0.0001,) and the data was homogenous (I^2=0% *p*=0.6). A subgroup meta-analysis with nine studies [5, 12, 30, 34-36, 40-42] (n=5,435) demonstrated that non chronic pain was associated with a 61% increased odds of falling (OR: 1.61, CI: 1.39 to 1.86, *p*<0.0001, I^2 = 4% *p*=0.4). See Figure 5.

Insert Figure 5 about here

Meta-regression

We conducted a number of meta-regression analyses using the mixed effects model with the available data for mean age or percentage of females, for both the pain/no-pain and fall/no-fall groups and neither moderator had any significant effect on the outcomes of any of the analysis.

Methodological Quality Assessment

The NOS scores were of acceptable quality for the case controlled (mean 6.28±0.48) and cohort studies (mean 6.6±0.84). Therefore, no studies warranted exclusion over concerns about methodological quality. The NOS scores are presented in Supplemental Table 2 (online).

Discussion

The present study involving over 17,000 older adults is to our knowledge the first systematic review and meta-analysis focussing on the association between pain and falls in community dwelling older adults. The global meta-analysis established that pain was associated with a 56% increased odds of falling. We conducted a number of subgroup analyses (according to method of falls ascertainment, location of pain and duration of pain) and consistently found that pain was associated with increased odds of falling. In addition, all of the 12 studies within the narrative review which reported an adjusted association statistic, demonstrated that pain was associated with increased risk of falling. This review also demonstrated that 50.5% of older adults with pain reported one or more falls over 12 months compared to 25.7% of the control group ($p<0.001$). This figure of falls is considerably higher than the 30% of community dwelling older adults that fall each year [4, 48-49].

A subgroup meta-analysis utilising prospective falls data established that the odds of falling were increased by over 70% for those with pain. Ascertaining falls with prospective measurement is regarded more accurate than retrospective recall, although there is still some debate around the optimal method to monitor falls [8, 50-51]. The data from this analysis was homogenous (I^2=0%) and for these reasons it may represent the most accurate association between pain and falls from all of our analyses. Our subgroup meta-analysis investigating the association between pain and falls recorded retrospectively (n=13,012) established a more moderate association with falling (OR: 1.43, CI: 1.22 to 1.69,) which is not surprising as the retrospective recall of falls is often under reported [52-53].

A previous review [2] only utilised prospective falls data to avoid reverse causality, which is clearly a consideration for our results where falls were obtained retrospectively. However, we attempted to negate this by excluding studies where participant's pain was identified from a previous fall. Retrospective recall of falls over 12 months is relatively specific (91-95%) although less sensitive than prospective measurement of falls [51]. The result that older adults with pain are 43% more likely to have fallen in the past year is important, since a history of falls is strongly associated with future falls [1-2, 51] and is commonly advocated as a valid indicator/ assessment in clinical practice [14].

We set out to establish if the location and duration of pain is associated with differing risks of falling since this information would provide valuable information to clinicians. Our meta-analysis established that foot pain was strongly associated with falls (n=691, OR: 2.38, CI: 1.62 to 3.4). We also established that hip pain was associated with falls (n=2,786, OR 1.36, CI: 1.00 to 1.84) which is in line with the adjusted association statistics reported from large cohort studies which established an increased risk when falls are measured retrospectively [18] or prospectively [44]. Our sub group analysis with older reporting knee pain (n=2,634) established that knee pain was not associated with falls. However, several individual studies reported knee pain is associated with an increased risk of falls when the pain is severe [37] or chronic [13]. We conducted an analysis of pain classified as 'other' (any bodily pain or non-knee, foot, hip or spinal pain) and found a pronounced increased odds of falling (OR: 1.54, CI: 1.25 to 1.88), but this data was heterogeneous. Finally, our subgroup meta-analysis with 5,367 older adults established that chronic pain was associated with increased odds of falling by 80% (OR 1.80, CI: 1.56 to 2.09, I^2=0%). This is in line with Leveille and colleagues' [6] study who demonstrated that chronic polyarticular pain was associated with a 70% increased risk of falling. We also conducted an analysis for non-chronic pain and this established the odds of falling was increased by 61% (OR: 1.61, CI: 1.39 to 1.86, I^2 = 4%).

The underlying reasons for the association between pain and falls are likely to be multifaceted, since pain in itself is a very complex phenomenon. Previous researchers [6] have postulated that the mechanisms by which chronic musculoskeletal pain increases the risk of falls may be the result of three possible causes: 1) local joint pathology (e.g. osteoarthritis), 2) the neuromuscular effects of pain and 3) central mechanisms, where pain interferes with the older adult's cognition and executive function. Another factor that could possibly contribute is psychological concerns related to falling (fear of falling, falls efficacy), since these are known to increase the risk of falls in their own right [2] and are associated with pain [54]. The strength of association between foot pain and chronic pain with falls is higher than several commonly considered risk factors such as cognitive impairment (OR 1.36, CI: 1.12 to 1.65, [2]), depression (OR

1.63, CI: 1.36 to 1.94[2]), visual impairment (OR 1.35, CI: 1.18 to 1.54[2]) and the use of sedative medication (OR 1.38, CI: 1.15 to 1.66) [2]. The results for our meta-analysis were consistently higher than the reported association between pain and falls reported in another review which only included two studies in the faller's category [2]. Our results suggest it is advisable that clinicians working within rehabilitation of the older person at risk of falling should routinely assess pain, paying particular attention to foot and chronic pain. In addition, clinicians working with older adults who present with pain ought to routinely ask the patient about their history of falls, recognising they may be at increased risk of future falls. Adequate pain management is likely to be very important in the older person's rehabilitation and may serve to reduce the risk of falls. The strong association of foot pain with falls advocates the importance of podiatrists within the rehabilitation multidisciplinary team to prevent falls. Previous research has demonstrated that multifaceted interventions delivered by podiatrists to older people with foot pain can have a reduction in the rate of falls which is comparable to other well established interventions such as tai chi [55].

Within this study we encountered a wide range of association statistics being utilised together with a plethora of adjustments for confounding factors making the meta-analysis very difficult. We contacted numerous authors and relied upon the unadjusted OR from the raw data for the meta-analysis. The use of adjusted OR are considered more reliable, however only considering the adjusted OR may lead to an over estimation of the influence of pain on falls [2]. We calculated the unadjusted OR and observed small differences compared to the reported adjusted association statistics in several instances [5-6, 38]. In addition, all 12 studies included in the narrative review that reported an adjusted association statistic established that pain increased the risk of falls.

Our review found 9 studies (43%) did not provide a definition for a fall, this is concerning but consistent with previous research in the wider falls literature [8, 19]. Standardisation in the definitions employed within research is essential to enable replication and also to enhance quality of research and enabling meta-analyses to be completed [53]. The PROFANE European falls network [19] offers an excellent comprehensive falls taxonomy that ensures continuity and consistency in research investigating falls. Most studies included within this review ascertained falls retrospectively, whilst this is still insightful, documentation of falls prospectively does have advantages in terms of accuracy and reducing concerns of reverse causality.

Limitations

It is important that a number of considerations are made when interpreting the results from this review. First, it is not possible to rule out reverse causality for the meta-analysis that incorporates the results of falls ascertained retrospectively. Second, the assessment and classification of pain in each study varied considerably and future research should seek to unify the way pain is defined and assessed and we have made recommendations for this elsewhere [56]. Third, we only conducted meta-analyses utilising unadjusted OR. In addition the information available on mean age, gender and comorbidity in each study was limited and we could not consistently adjust for these in each analysis. In order to explore the influence of age and gender on the observed effects, we conducted numerous meta-regression analyses with these factors as moderators and none reached statistical significance. In addition within each study, two reviewers independently considered age, gender or comorbidity in the NOS. Age was met in all but one study whilst only 11 met the criteria for gender or comorbidity since the information was not clear in a further 8 studies. Although we attempted to exclude certain comorbidities in our exclusion criteria (e.g. stroke, dementia) it is possible that other comorbidities (e.g. osteoarthritis) were present among the study populations and could have influenced the observed effects [23]. We only conducted a review of the methodological quality of included articles and did not conduct a specific risk of bias assessment. This is now recommended by the Cochrane collaboration and may have affected the interpretation of our results. In addition, we did not consider articles that were not written in English and we may have missed some data. We also excluded studies conducted in individuals with dementia, neurological conditions and recent orthopaedic trauma since this would have introduced further heterogeneity in our sample and may have impacted the results. Finally, we did not consider single and recurrent fallers separately and since this is an at risk group this warrants further exploration.

Future research

Only twelve studies included in this review reported an association statistic for the relationship between pain and falls and very few set out to investigate this as their primary aim. This exemplifies the low consideration given within the literature to investigate pain as an independent risk factor for falls. Future research should clearly assess the location, duration and severity of pain in older adults [56] and falls ascertained prospectively for 12 months [19]. The research should follow the reporting of falls trials suggested by the PROFANE falls network [19]. This would enable accurate associations to be established between pain and falls, avoid problems with reverse causality and ensure future meta-analyses are less complex. A number of studies [6, 13, 39, 43] established that the risk of multiple falls is higher than single falls for older adults with pain and this warrants investigation in well conducted clinical trials. We did not encounter any randomised controlled trials (RCT's) investigating the relationship between pain and falls. A RCT would provide higher quality evidence to explore this relationship and reduce concerns about the risk of bias. Future prospective RCT's could consider a screening and intervention for those with pain versus normal care and consider falls rates thereafter.

Conclusions

The results of this meta-analysis established that older adults with pain are at increased risk of falls. We found that 50.5% older adults with pain reported one or more falls in a year compared to 25.7% ($p<0.001$) in those without pain. In addition, we found that foot pain and chronic pain were strongly associated with falls in community dwelling older adults. Clinicians completing falls risk assessments should routinely enquire about the older person's current pain and pay particular attention to foot and chronic pain. There is a need for well-designed prospective epidemiological studies to further establish this link which can inform future intervention studies to manage pain in older people which in turn may reduce the risk of falls in clinical practice.

Conflict of Interest

None to declare by any author

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Figure listings

Figure 1 – PRISMA search strategy

Figure 2a. Global Meta-analysis for all studies investigating the association of pain with falls

Figure 2b – funnel plot of included studies for global meta-analysis

Figure 3. Meta-analysis comparing falls data collected prospectively and retrospectively

Figure 4. Sub group Meta-analysis investigating location of pain and association with falls

Figure 5. Sub group Meta-analysis investigating the association of chronic and non-chronic pain with Falls

ACCEPTED MANUSCRIPT

Example search strategy using MESH headings

1. Pain and fall*
2. Musculoskeletal pain and falls
3. Pain and accidental falls
4. Musculoskeletal pain and accidental falls
5. Chronic pain and falls
6. Chronic musculoskeletal pain and falls
7. Chronic pain and accidental falls
8. Chronic musculoskeletal pain and falls
9. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 AND older adult
10. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 AND elderly
11. 1 OR 2 OR 3 OR 4 OR 5 OR 6 OR 7 OR 8 AND aged

Table 1. Adjusted Association statistics and Unadjusted Odd ratios

Study	Pain	Falls Ascertainment	Association Statistic for falls risk	Adjusted for
Hip Pain				
Arden et al 1999	Chronic Hip pain	12 months (R)	RR 1.5 (CI: 1.3 to 1.8) *for 2> falls*	Age, knee height, weight, clinic.
Leveille et al 2009	Chronic Hip pain	18 months (P)	RaR 1.23 (CI: 0.56 to 2.69)	≠
Nevitt et al 1989	Current hip/ knee pain	12 months (P)	RR 1.9 (CI: 1.3 to 3.7) *for 2> falls*	Unadjusted
Cecchi et al 2009	Hip pain over last 4 weeks	12 months (R)	OR 1.33 (0.85 to 2.10) P = 0.2082	Raw Data
Nahit et al 1998	Current Hip pain	12 months (R)	OR 1.70 (0.90-3.21) p= 0.0976	Raw Data
Woo et al 2009	Chronic Hip pain	12 months (R)	OR 1.16 (0.66-2.03) p=0.5879	Raw Data
Knee pain				
Arden et al 2006	Knee pain over last month	6 months (R)	HR: 1.26 (CI: 1.17 to 1.36)	Unclear
Arden et al 2006	Severe knee pain over last month	6 months (R)	HR: 1.51 (CI:1.32 to 1.72)	Unclear
Leveille et al 2009	Chronic Knee pain	18 months (P)	RaR 0.95 (CI 0.60 to1.49)	≠
Muraki et al 2011	Chronic Knee pain	12 months (R)	1> fall OR 1.20 (CI: 0.79 to 1.81) 1> fall OR 1.00 (CI: 0.62 to 1.61) 1> fall OR 0.99 (CI: 0.60 to 1.61) 2> fall OR 2.52 (CI: 1.58 to 4.02) 2> fall OR 1.61 (CI: 0.92 to 2.79)	Unadjusted † ‡ Unadjusted †

Table 1. Adjusted Association statistics and Unadjusted Odd ratios

			2> fall OR 1.87 (CI: 1.06 to 3.28)	‡
Cecchi et al 2009	Knee pain over last 4 weeks	12 months (R)	OR 1.75 (CI =1.26 to 2.45) P = 0.0009*	Raw data
Levinger et al 2011	Current knee pain	12 months (R)	OR 2.24 (0.77 to 6.46) P = 0.1349	Raw data
Woo et al 2009	Chronic knee pain	12 months (R)	OR 1.0039 (0.72-1.39) p=0.9813	Raw data
Back/ Neck Pain				
Bekibele & Gureje 2010	Chronic Back/ neck pain	12 months (R)	OR 1.3 (CI: 1.0 to 1.7)	Age & gender
Leveille et al 2009	Chronic back pain	18 months (P)	RaR 1.37 (CI: 0.75 to 2.50)	≠
Morris et al 2004	Chronic Back pain	12 months (R)	1 > fall OR 1.54 (CI: 1.10 to 2.16) P=0.01*	Unadjusted
			2> Fall OR 3.90 (CI: 2.49 to 6.16) P<0.001*	Unadjusted
Muraki et al 2011	Chronic LBP	12 months (R)	1> fall OR 1.28 (CI: 0.82 to 1.96)	Unadjusted
			1> OR fall 1.34 (CI: 0.84 to 2.08)	†
			1> fall OR 1.33 (CI: 0.84 to 2.08)	‡
			2> fall OR 2.14 (CI: 1.30 to 3.46)	Unadjusted
			2> fall OR 1.72 (CI: 1.01 to 2.88)	†
			2> fall OR 1.58 (CI: 0.91 to 2.70)	‡
Woo et al 2009	Chronic back pain	12 months (R)	OR 1.14 (0.85-1.51) p=0.3625	Raw data
	Chronic back pain causing interference with activities		OR 0.87 (0.48-1.56) p=0.6474	Raw data
Foot Pain				

Table 1. Adjusted Association statistics and Unadjusted Odd ratios

Leveille et al 2009	Chronic foot pain	18 months (P)	RaR 1.07 (CI: 0.62 to 1.84)	≠
Chaiwanichsiri et al 2009	Current foot pain	6 months (R)	OR 3.60 (1.59 to 8.16) P = 0.0021*	Raw data
Chaiwanichsiri et al 2009	Current foot pain	6 months (R)	OR 2.5 (1.03 to 6.12) p=0.043*	Unclear
Menz et al 2006	Foot pain over last month	12 months (P)	OR 2.84 (1.35-5.95) p=0.0056*	Raw data
Mickle et al 2010	Current foot pain	12 months (P)	OR 1.87 (1.16-3.02) p=0.0098*	Raw data

Unspecified/ Any Body Pain

Bekibele & Gureje 2010	Chronic body pain	12 month (R)	OR 1. .96 (1.51 to 2.55) P<0.0001*	Raw data
Bekibele & Gureje 2010	Chronic body pain	12 months (R)	OR 1.9 (CI: 1.1 to 3.4)	Age and gender
Dai et al 2012	Current body pain	12 months (P)	OR 1.37 (CI: 0.87 to 2.14) p=0.1648	Raw Data
Kwan et al 2013	Current Body pain	12 months (P)	OR 1.46 (1.078 – 1.985) P=0.014*	Raw data
Kwan et al 2013	Current body pain	12-18 months prospective	IRR: 1.40 (CI: 1.08 to 1.80)	Age and gender
Morris et al 2004	Chronic body pain frequency 'sometimes'	12 months (R)	1>Fall OR 1.52 (CI: 0.98 to 2.35) P=0.06 2> fall OR 2.52 (CI: 1.41 to 4.51) P=0.002*	Unadjusted

Table 1. Adjusted Association statistics and Unadjusted Odd ratios

	Chronic body pain 'frequent'		1> fall OR 1.19 (CI: 0.80 to 1.77) 2> fall OR 2.86 (CI: 1.74 to 4.71) P<0.001*	Unadjusted
Woo et al 2009	Chronic pain mixed	4 year (P)	OR 1.67(1.34-2.08) p=0.0000*	Raw data
Yagci et al 2007	Chronic body pain	12 months (R)	OR 11.79 (2.76- 50.26) P = 0.0008*	Raw data
Tromp et al 1998	Current body pain	12 months (R)	1>fall OR 1.1 (CI: 1.0 to 1.2) p< 0.05* 2> OR 1.2 (CI: 1.1 to 1.4) P< 0.05*	Unclear

Single site vs. Widespread Pain

Leveille et al 2002	Other pain last month	Risk of falls over 3 year follow up	OR 1.36 (CI: 1.02 to 1.82)	**£**
	Lower extremity pain last month		OR 1.27 (CI: 0.97 to 1.66)	**£**
	Widespread pain last month	Risk recurrent falls over 6 months	OR 1.66 (CI: 1.25 to 2.21)	**£**
	Other pain last month		OR 1.54 (CI: 1.01 to 2.35)	**£**
	Lower extremity pain last month		OR 1.38 (CI: 0.93 to 2.03)	**£**
	Widespread pain last month		OR 1.66 (CI: 1.10 to 2.50)	**£**
Leveille et al 2002	Pain over last month:	12 months (R)		
	Pooled pain data of all types of pain		OR 1.39 (1.00 -1.92) p=0.0450*	Raw data
	Other pain		OR 1.39 (0.92-2.099)	Raw data
	Lower extremity pain		OR 1.17 (0.807-1.714)	Raw data

Table 1. Adjusted Association statistics and Unadjusted Odd ratios

	Widespread pain		OR 1.718 (1.16-2.53) p=0.007*	Raw data
Leveille et al 2009	Chronic pain overall: Single site Polyarticular	12 months (R)	OR 1.83 (1.33-2.53) p=0.000* OR 1.57 (1.05 - 2.35) P = 0.0261* OR 2.01 (1.41 - 2.85) P = 0.0001*	Raw data Raw data Raw data
Leveille et al 2009	Single site pain Polyarticular pain	18 months (P)	RaR 1.19 (CI: 0.90 to 1.56) RaR 1.70 (CI: 1.34 to 2.20)	Age, sex, education
Leveille et al 2009	Pooled chronic pain	12 months (P)	OR 1.86(CI: 1.37 to 2.52 p=0.0001*	Raw data
Pain severity / interference with activity				
Blyth et al 2007	Pain last 4 weeks & interference with activity	12 months (R)	*No interference* 1>fall PR 1.15 (CI: 0.97 to 1.37) 2>PR 1.31 (CI: 0.92 to 1.86) *Slight interference* 1>fall PR 1.37 (CI: 1.16 to 1.62) 0.0002* 2>fall PR 1.66 (CI: 1.19 to 2.33) 0.0032* *Moderate interference* 1>fall PR 1.72 (CI : 1.47 to 2.00) <0.0001* 2> PR 2.29 (CI: 1.67 to 3.13) <0.0001*	Age & Gender

Table 1. Adjusted Association statistics and Unadjusted Odd ratios

Sturneiks et al 2004	Severity of pain:	12 months (R)		
	Pooled pain data		OR 1.57 (CI: 1.14 to 2.18)p=0.0059	Raw data
	A bit of pain		OR 1.27 (CI=0.82 to 1.95) P = 0.2734	Raw data
	Moderate pain		OR 1.41 (CI=0.85 to 2.34) P = 0.1810	Raw data
	Quite a lot of pain		OR 2.58 (CI=1.41 to 4.71) P = 0.0019*	Raw data
	A lot of pain		OR 10.74 (CI=0.55 to 209.38) P = 0.1171	Raw data
Leveille et al 2009	Chronic Pain severity	18 months (P)	Moderate RaR 1.19 (0.92-1.53) High RaR 1.54 1.18-2.01)	Age, gender & education
	Chronic pain interference with activities		Moderate Interference: RaR 1.44 (1.11-1.85) High Interference: RaR 1.67 (1.31-2.14)	

Key

RR – Relative risk HR – Hazard ratio (P) – Prospective ascertainment of falls (R) – Retrospective ascertainment of falls

RaR – Rate Ratio OR – Odds Ratio IRR – Incidence risk ratio PR – Prevalence ratio LBP – low back pain

Raw data – unadjusted OR calculated from raw data

Key for Adjustment of confounding factors:

≠= Leveille et al 2009 binomial regression - age, sex, race, education, heart disease, diabetes, Parkinson disease, history of stroke, vision score, body mass index, neuropathy, cognitive function, physical activity, balance test score, repeated chair stand time, gait speed, use of psychotherapeutic medications, daily use of analgesic medications, hand and knee osteoarthritis clinical criteria excluding pain

† = Muraki et al 2011 multinomial logistic regression analysis with age, body mass index, cognitive impairment, radiographic knee OA, knee pain, radiographic LS, and lower back pain as independent variables

Table 1. Adjusted Association statistics and Unadjusted Odd ratios

‡ = Muraki et al 2011 multinomial logistic regression analysis with grip strength, 6-meter walking time, and chair stand time in addition to † independent variables

£ - Leveille et al 2002 - Adjusted from discrete time survival analysis (using logistic regression), updating pain level to most recent follow-up interview before event. Covariates included age, race, education, body-mass index, confirmed diseases (hip fracture, angina pectoris, diabetes mellitus, peripheral arterial disease, stroke, Parkinson's disease), walking disability, fell in 12 months before baseline, Mini-Mental State Examination score, daily use of psychoactive medications, daily use of analgesic medications, gait speed, balance test score, proxy respondent, and follow-up round.

Figure 1. PRISMA 2009 flow diagram for search strategy

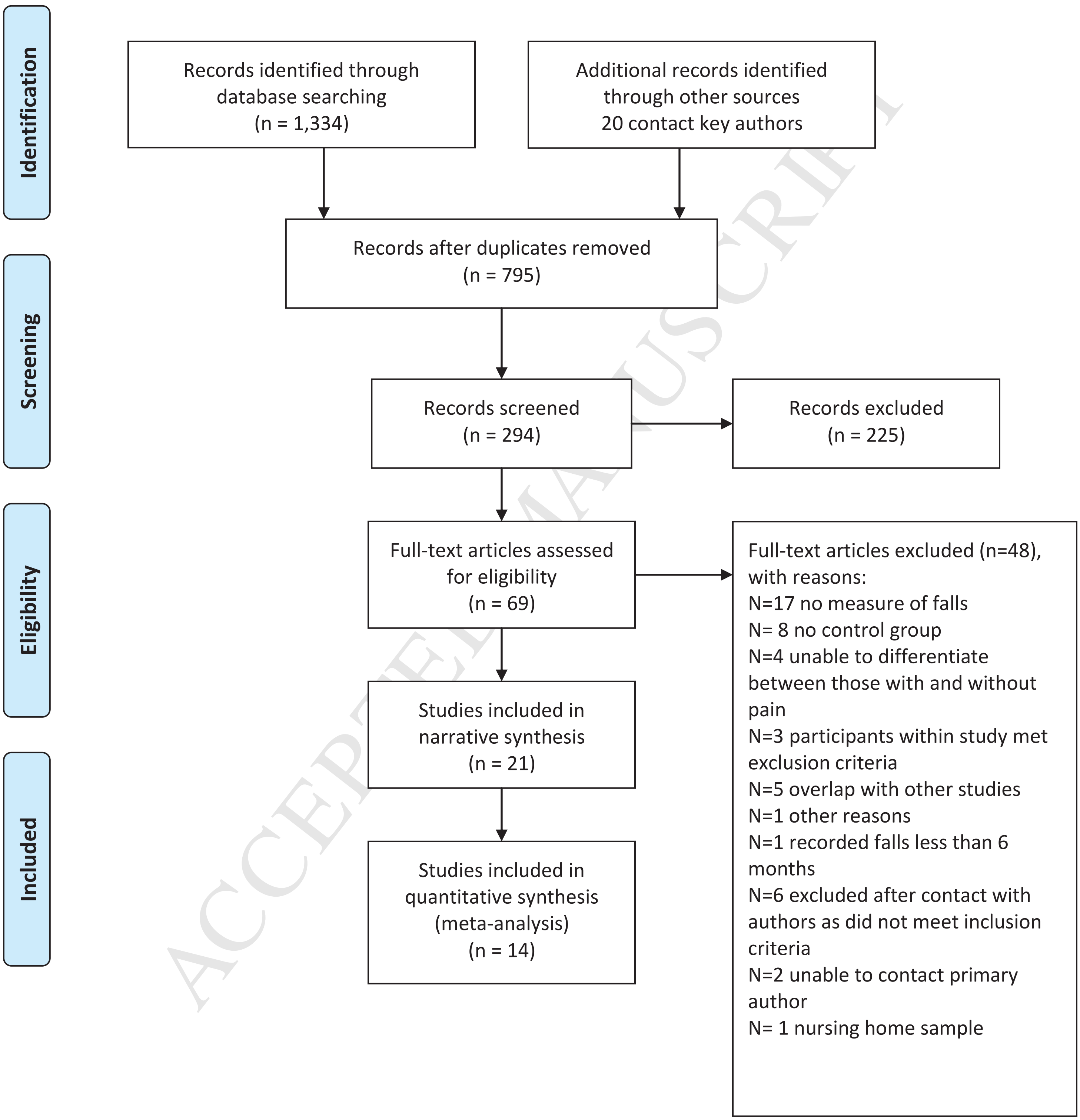


Figure 2a. Global Meta-analysis for all studies investigating the association of pain with falls (Online supplementary file)

Model	Study name	Subgroup within study	Statistics for each study				Fall / Total	
			Odds ratio	Lower limit	Upper limit	p-Value	Pain	No-Pain
	Cecchi et al 2009	Hip Pain	1.338	0.850	2.107	0.208	29 / 110	187 / 886
	Cecchi et al 2009	Knee Pain	1.758	1.260	2.453	0.001	69 / 225	157 / 781
	Chaiwanichsiri et al 2009	Foot pain	3.608	1.595	8.166	0.002	13 / 30	32 / 183
	Dai et al 2012	Current Pain	1.373	0.878	2.148	0.165	38 / 118	101 / 393
	Levinger et al 2011	Knee Pain	2.243	0.778	6.469	0.135	17 / 35	8 / 27
	Menz et al 2006	Foot pain	2.843	1.358	5.954	0.006	23 / 38	48 / 137
	Mickle et al 2010	Foot pain	1.876	1.164	3.023	0.010	62 / 107	83 / 196
	Nahit et al 1998	Hip Pain	1.707	0.907	3.213	0.098	23 / 76	30 / 148
	Woo et al 2009	Back Pain	1.141	0.859	1.514	0.362	92 / 555	150 / 1011
	Woo et al 2009	Back pain-interferance	0.873	0.488	1.562	0.647	14 / 101	228 / 1465
	Woo et al 2009	Chronic pain	1.677	1.346	2.089	0.000	173 / 393	658 / 2061
	Woo et al 2009	Hip Pain	1.167	0.668	2.038	0.588	16 / 91	228 / 1475
	Woo et al 2009	Knee Pain	1.004	0.724	1.392	0.981	55 / 355	187 / 1211
	Yagci et al 2007	Lower Body	11.794	2.768	50.262	0.001	39 / 163	2 / 77
	Leveille et al 2002	Pooled pain data	1.393	1.007	1.926	0.045	251 / 707	66 / 233
	Sturneiks et al 2004	Pooled pain data	1.577	1.140	2.181	0.006	117 / 231	164 / 416
	Leveille et al 2009	Pooled pain data	1.862	1.375	2.522	0.000	257 / 493	100 / 271
	Bekibele & Gureje 2010	Chronic Pain	1.967	1.514	2.557	0.000	1479 / 1700	347 / 449
	Kwan et al 2013	Current activity limiting pain	1.463	1.078	1.986	0.015	90 / 297	156 / 681
Random			1.562	1.362	1.791	0.000		

Odds ratio and 95% CI

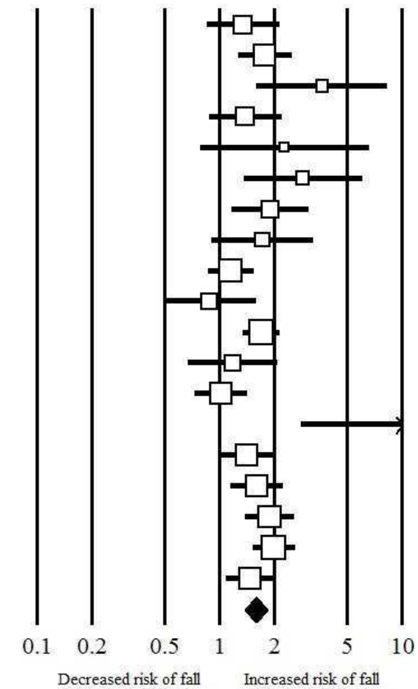


Figure 2b. Funnel plot to assess risk of bias in Global Meta-analysis

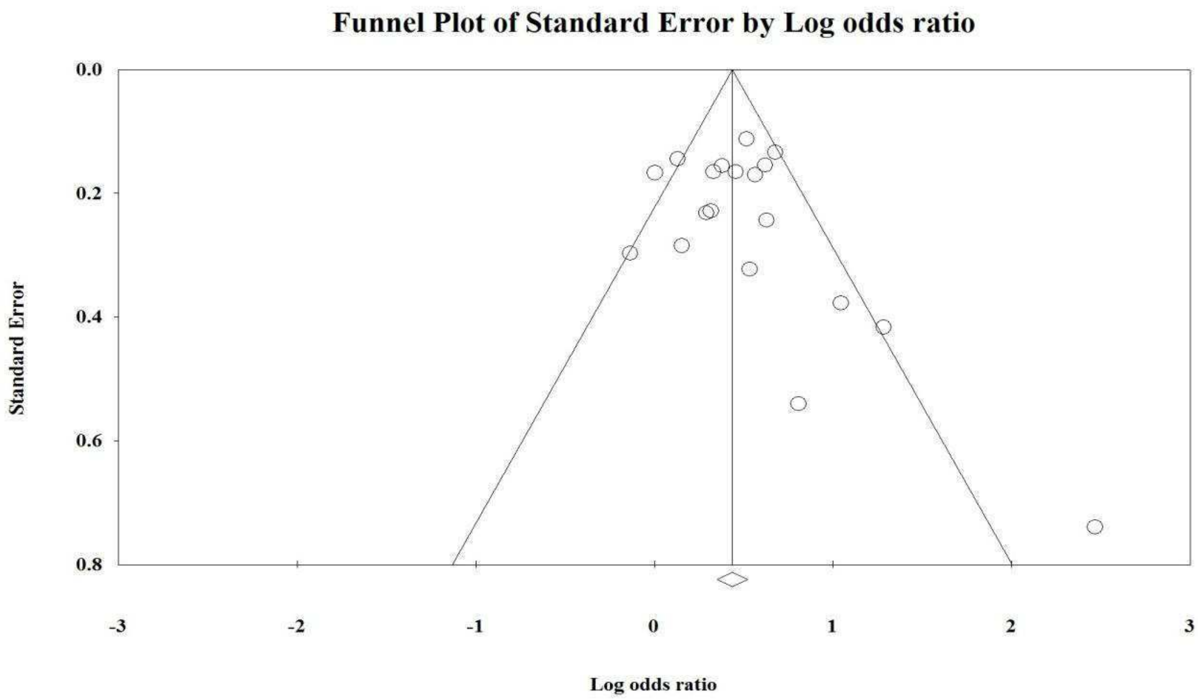


Figure 3. Meta-analysis comparing falls data collected prospectively and retrospectively

Model	Group by Design	Study name	Subgroup within study	Statistics for each study: Odds ratio	Lower limit	Upper limit	p-Value	Fall / Total: Pain	No-Pain
	Prospective	Menz et al 2006	Foot pain	2.843	1.358	5.954	0.006	23 / 38	48 / 137
	Prospective	Mickle et al 2010	Foot pain	1.876	1.164	3.023	0.010	62 / 107	83 / 196
	Prospective	Woo et al 2009	Chronic pain	1.677	1.346	2.089	0.000	173 / 393	658 / 2061
	Prospective	Leveille et al 2009	Pooled pain data	1.862	1.375	2.522	0.000	257 / 493	100 / 271
	Prospective	Kwan et al 2013	Current activity limiting pain	1.463	1.078	1.986	0.015	90 / 297	156 / 681
Random	Prospective			1.716	1.487	1.981	0.000		
	Retrospective	Cecchi et al 2009	Hip Pain	1.338	0.850	2.107	0.208	29 / 110	187 / 886
	Retrospective	Cecchi et al 2009	Knee Pain	1.758	1.260	2.453	0.001	69 / 225	157 / 781
	Retrospective	Chaiwanichsiri et al 2009	Foot pain	3.608	1.595	8.166	0.002	13 / 30	32 / 183
	Retrospective	Dai et al 2012	Current Pain	1.373	0.878	2.148	0.165	38 / 118	101 / 393
	Retrospective	Levinger et al 2011	Knee Pain	2.243	0.778	6.469	0.135	17 / 35	8 / 27
	Retrospective	Nahit et al 1998	Hip Pain	1.707	0.907	3.213	0.098	23 / 76	30 / 148
	Retrospective	Woo et al 2009	Back Pain	1.141	0.859	1.514	0.362	92 / 555	150 / 1011
	Retrospective	Woo et al 2009	Back pain-interferance	0.873	0.488	1.562	0.647	14 / 101	228 / 1465
	Retrospective	Woo et al 2009	Hip Pain	1.167	0.668	2.038	0.588	16 / 91	228 / 1475
	Retrospective	Woo et al 2009	Knee Pain	1.004	0.724	1.392	0.981	55 / 355	187 / 1211
	Retrospective	Leveille et al 2002	Pooled pain data	1.393	1.007	1.926	0.045	251 / 707	66 / 233
	Retrospective	Sturneiks et al 2004	Pooled pain data	1.577	1.140	2.181	0.006	117 / 231	164 / 416
	Retrospective	Bekibele & Gureje 2010	Chronic Pain	1.967	1.514	2.557	0.000	1479 / 1700	347 / 449
Random	Retrospective			1.439	1.222	1.694	0.000		

Odds ratio and 95% CI

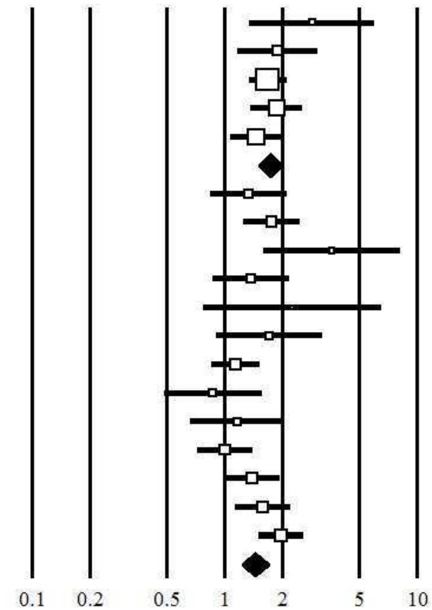


Figure 4. Sub group Meta-analysis investigating location of pain and association with falls

Model	Group by Site specific	Study name	Subgroup within study	Odds ratio	Lower limit	Upper limit	p-Value	Design	Fall / Total Pain	Fall / Total No-Pain
	Foot	Chaiwanichsiri et al 2009	Foot Pain	3.608	1.595	8.166	0.002	Retrospective	13 / 30	32 / 183
	Foot	Menz et al 2006	Foot pain	2.843	1.358	5.954	0.006	Prospective	23 / 38	48 / 137
	Foot	Mickle et al 2010	Foot pain	1.876	1.164	3.023	0.010	Prospective	62 / 107	83 / 196
Random	Foot			2.380	1.626	3.483	0.000			
	Hip	Cecchi et al 2009	Hip Pain	1.338	0.850	2.107	0.208	Retrospective	29 / 110	187 / 886
	Hip	Nahit et al 1998	Hip Pain	1.707	0.907	3.213	0.098	Retrospective	23 / 76	30 / 148
	Hip	Woo et al 2009	Hip Pain	1.167	0.668	2.038	0.588	Retrospective	16 / 91	228 / 1475
Random	Hip			1.360	1.000	1.849	0.050			
	Knee	Cecchi et al 2009	Knee Pain	1.758	1.260	2.453	0.001	Retrospective	69 / 225	157 / 781
	Knee	Levinger et al 2011	Knee Pain	2.243	0.778	6.469	0.135	Retrospective	17 / 35	8 / 27
	Knee	Woo et al 2009	Knee Pain	1.004	0.724	1.392	0.981	Retrospective	55 / 355	187 / 1211
Random	Knee			1.434	0.890	2.311	0.139			
	Other	Woo et al 2009	Back Pain	1.141	0.859	1.514	0.362	Retrospective	92 / 555	150 / 1011
	Other	Leveille et al 2002	Pooled pain data	1.393	1.007	1.926	0.045	Retrospective	251 / 707	66 / 233
	Other	Leveille et al 2009	Pooled pain data	1.862	1.375	2.522	0.000	Prospective	257 / 493	100 / 271
	Other	Bekibele & Gureje 2010	Chronic Pain	1.967	1.514	2.557	0.000	Retrospective	1479 / 1700	347 / 449
	Other	Kwan et al 2013	Current activity limiting pain	1.463	1.078	1.986	0.015	Prospective	90 / 297	156 / 681
Random	Other			1.540	1.255	1.890	0.000			

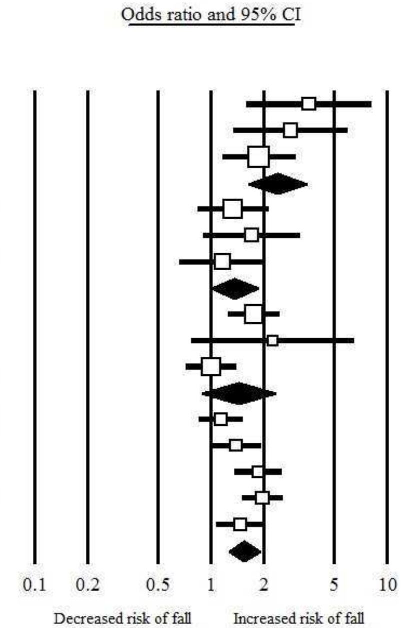
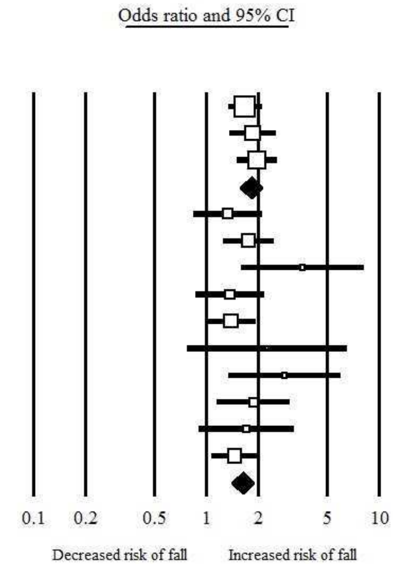


Figure 5. Sub group Meta-analysis investigating the association of chronic and non-chronic pain with falls

Model	Group by Duration of Pain	Study name	Subgroup within study	Odds ratio	Lower limit	Upper limit	p-Value	Design	Fall / Total: Pain	Fall / Total: No-Pain
	Chronic	Woo et al 2009	Chronic pain	1.677	1.346	2.089	0.000	Prospective	173 / 393	658 / 2061
	Chronic	Leveille et al 2009	Pooled pain data	1.862	1.375	2.522	0.000	Prospective	257 / 493	100 / 271
	Chronic	Bekibele & Gureje 2010	Chronic Pain	1.967	1.514	2.557	0.000	Retrospective	1479 / 1700	347 / 449
Random	Chronic			1.807	1.560	2.094	0.000			
	Non-chronic	Cecchi et al 2009	Hip Pain	1.338	0.850	2.107	0.208	Retrospective	29 / 110	187 / 886
	Non-chronic	Cecchi et al 2009	Knee Pain	1.758	1.260	2.453	0.001	Retrospective	69 / 225	157 / 781
	Non-chronic	Chaiwanichsiri et al 2009	Foot Pain	3.608	1.595	8.166	0.002	Retrospective	13 / 30	32 / 183
	Non-chronic	Dai et al 2012	Current Pain	1.373	0.878	2.148	0.165	Retrospective	38 / 118	101 / 393
	Non-chronic	Leveille et al 2002	Pooled Pain data	1.393	1.007	1.926	0.045	Retrospective	251 / 707	66 / 233
	Non-chronic	Levinger et al 2011	Knee Pain	2.243	0.778	6.469	0.135	Retrospective	17 / 35	8 / 27
	Non-chronic	Menz et al 2006	Foot pain	2.843	1.358	5.954	0.006	Prospective	23 / 38	48 / 137
	Non-chronic	Mickle et al 2010	Foot pain	1.876	1.164	3.023	0.010	Prospective	62 / 107	83 / 196
	Non-chronic	Nahit et al 1998	Hip Pain	1.707	0.907	3.213	0.098	Retrospective	23 / 76	30 / 148
	Non-chronic	Kwan et al 2013	Current activity limiting pain	1.463	1.078	1.986	0.015	Prospective	90 / 297	156 / 681
Random	Non-chronic			1.617	1.398	1.870	0.000			



Supplemental Table S1 Summary of included studies

Study	Design	Setting	Participant information	Pain ascertainment location severity	Falls reference period	Mode of falls assessment	Definition of falls	Prevalence of Falls (1≥ falls)
Arden et al 1999	Cohort study	Community (USA)	N = 5552 71.4 ± 5.1 years 100% female 60.6% confirmed they had self-report physician diagnosed OA. 11.6% had definite radiographic hip OA. Cases matched for both groups. Excluded for RA, Paget's disease, previous hip fracture/ surgery.	Self-report chronic hip pain over 12 months. Chronic hip pain N = 1914 (34.5%) sample	(R) 12 months	Number of falls in first 12 month follows up. Asked about falls every 4 months.	Not given	Not given
Arden et al 2006	Cross-sectional	Community (UK)	Total N = 6641 N = 4026 no knee pain: 78.7 years (76.7 - 81.5) 50.8% female = 1427 prevalent knee pain 78.6 years (76.7 - 81.3 ns) 56.3% females (p<0.01). Excluded for renal failure, bilateral hip replacement & current cancer. Patient with knee pain more likely to use walking aid (p<0.001).	Asked if had pain around the knee had most / all days in last month.	(R) 6 months	Questionnaire for falls history	Not given	Not given

Supplemental Table S1 Summary of included studies

Study	Design	Setting	Participant information	Pain ascertainment location severity	Falls reference period	Mode of falls assessment	Definition of falls	Prevalence of Falls (1≥ falls)
Bekibele & Gureje 2010	Cross-sectional	Community (NGA)	N = 2,096 75.0 ± 9.2 years 47.5% female N = 1700 with chronic pain Fallers 75.2 years vs. non fallers 75.1 years (ns) 78.1% fallers had arthritis vs. 67.7% without arthritis who fell (OR 1.7, CI: 1.0 to 2.7)	Questionnaire on persistent pain in last 12 months	(R) 12 months	Questionnaire for falls history	Not given	(R) Chronic Body pain 87.0% vs. no pain 77.3% (R) Chronic back pain 56.9% vs. no pain 50.1%
Blyth et al 2007	Cross-sectional	Community (AU)	N = 3181 65.1% female N = 2227 pain in last 4 weeks (with or without interfering with activity) N = 710 slight pain causing interference N = 711 moderate-severe pain causing interference N = 784 no pain Fallers more likely to use walking aid (*p*<0.0001), have history of stroke (*p*<0.0001), arthritis (*p*<0.0001) use psychotropic medication (*p*<0.0001)	SF 36 – bodily pain and pain interfering with activities. Last 4 weeks.	(R) 12 months	Questionnaire for falls history	No reference 'During the past 12 months, have you had any falls where you have landed on the ground or floor'	(R)Pain over last 4 weeks: No interference 25.6% Slight interference 23.1% Moderate/ severe pain 23.2% vs. no pain 28.1%

Supplemental Table S1 Summary of included studies

Study	Design	Setting	Participant information	Pain ascertainment location severity	Falls reference period	Mode of falls assessment	Definition of falls	Prevalence of Falls (1≥ falls)
Cecchi et al 2009	Cohort	Community (IT)	N = 1006 75.2 ± 7.1 years 56.1% female N = 120 with hip pain: Pain 76.2% females No pain 53.4% females (*p* <0.01) Pain 75.2 ± 7.2 years No pain 75.2 ± 7.1 years (ns) N = 225 with knee pain: Pain 74.3% females No pain 50.9% females (*p* <0.01) Pain = 75.4 ± 6.9 No pain = 75.2 ± 7.2 (ns) Covariates: hypertension, peripheral artery diseases, stroke, cardiovascular disease and depression. Foot pain was present in 16-30% of participants.	Questionnaire literature 'over the past four weeks, did you ever experience hip/ knee pain?' Also completed WOMAC	(R) 12 months	Questionnaire of if fallen 1≥ times in past 12 months	'An incident resulting in the participant coming unexpected-ly to the ground'. No reference	(R) Hip pain 32.5% vs. no hip pain 21.1% *p* = 0.027 (R) Knee pain 30.7% vs. no knee pain 20.1% *p* = 0.01

Supplemental Table S1 Summary of included studies

Study	Design	Setting	Participant information	Pain ascertainment location severity	Falls reference period	Mode of falls assessment	Definition of falls	Prevalence of Falls (1≥ falls)
Chaiwanichsiri et al 2009	Cross-sectional	Community (TH)	N = 213 68.6 ± 5.4 years 49.2% female N = 30 with foot pain Male: Fallers 70.2 ± 6.4 years Non fall 68.4 ± 5.0years Significant *p*< 0.001 Female: Fallers 69.5 ± 4.2 years Non fall 68.2 ± 6.0 years (ns) Fallers more likely to be female (*p*<0.05), have knee OA (*p*<0.05)	Foot pain confirmed by physician. Duration/ severity unknown	(R) 6 months	Interview history of falls	Not given	(R) ≥1 Fall over 6 months Males with foot pain 7.1% vs. no pain 5.3% Females with foot pain 38.7% vs. no pain 16.2%
Dai et al 2012	Cross-sectional	Community (USA)	N = 511 N = 372 non fall group: 71 ± 9.3 years 56.9% female N = 139 in fall group: 75 ± 11 years (*p*<0.01) 68.3% female 23% had pain Excluded only if physician or	Current bodily pain confirmed via questionnaire. No details on location & duration	(R) 12 months	Questionnaire history of falls	Not given	Current pain 32.2% vs. no pain 25.7%

Supplemental Table S1 Summary of included studies

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Study	Design	Setting	Participant information	Pain ascertainment location severity	Falls reference period	Mode of falls assessment	Definition of falls	Prevalence of Falls (1≥ falls)
Kwan et al 2013	Cohort	Community (TW, CN & AU)	N = 1456 N = 692 Chinese and Taiwanese: 74.9 ± 6.4 years 59.4% female N = 764 White Australians: 77.6 ±4.7 years 56% female 28% (277/ 989)[1] had pain interfering with activity. Comorbidities analysed were cerebro- and cardiovascular conditions, diabetes, osteoarthritis, incontinence, dizziness, Parkinson's disease and depressive symptoms. Separate comorbidity data for each groups were not available.	Questionnaire on current pain interfering with activity. No details on location & duration	(P) 12-24 months	Chinese sample: monthly telephone calls for 12-24 months. Australian white sample monthly falls calendars 12-24 months.	Gibson et al 1987 [46]	Not given

[1] Raw data provided by authors

Supplemental Table S1 Summary of included studies

Study	Design	Setting	Participant information	Pain ascertainment location severity	Falls reference period	Mode of falls assessment	Definition of falls	Prevalence of Falls (1≥ falls)
Leveille et al 2002	Cohort	Community (USA)	N = 1002 100% female N = 295 no pain N = 189 other pain N = 293 lower extremity pain N = 225 widespread pain Age (years) No pain 80.2 ± 8.1 Other pain 78.8 ± 7.7 Lower extremity pain 77.3 ± 8.4 Widespread pain 76.5 ± 7.3 (p<0.001) OA of knee: No pain 12.9% Other pain 30.7% Lower extremity 49.8% widespread pain 49.3% (p<0.001). OA of hip No pain 1.2%, Other pain 7.4% Lower extremity pain 11.6% Widespread pain 11.6%	NRS for hip and knee pain over past month	(R) 12 months	Interview on falls history past 12 months. Home interview every 6 months to establish further falls	Not given	(R) Other pain 35.5% (R) Lower extremity pain 31.9% (R) Widespread pain 40.4% vs. no pain 28.5%

Supplemental Table S1 Summary of included studies

Study	Design	Setting	Participant information	Pain ascertainment location severity	Falls reference period	Mode of falls assess	Definition of falls	Prevalence of Falls (1≥ falls)
Leveille et al 2009	Cohort	Community (USA)	N = 748 All >70 years 63.2% female N = 267 no pain (35.6%) N = 181 single site pain (24.2%) N = 300 polyarticular pain (40.1%) OA at any site: No pain 11.6% Single site 35.9% Polyarticular 60.5% (p<0.01) RA: No pain 2.6% Single site pain 3.9% Polyarticular pain 8.0% p=0.03 Polyarticular group also more likely to have depression (p<0.01) and peripheral arterial disease (p<0.01) and heart disease (p=0.008).	13 item joint pain questionnaire to establish chronic pain in hands, wrist, shoulders, back, chest, hips, knees and feet. Chronic pain ≥3 months.	(R) 12 months & (P) up to 18 months	Retrospective 12 months falls history questionnaire. Prospective monthly falls calendars for up to 18 months and follow up telephone calls	Gibson et al [46]	(R) Single site pain 38.3% (R) Polyarticular pain 44.2% vs. no pain 28.3%

Supplemental Table S1 Summary of included studies

Study	**Design**	**Setting**	**Participant information**	**Pain ascertainment location severity**	**Falls reference period**	**Mode of falls assessment**	**Definition of falls**	**Prevalence of Falls (1≥ falls)**
Levinger et al 2011	Case-controlled	Community (AU)	N = 62 OA group: N = 35, 67 ± 7 years 45% female. All had OA and knee pain. Control group: N = 27 65 ± 11 years (ns) 53% female (ns) Neither OA nor pain in knees.	WOMAC. Current pain/ severity unknown	(R) 12 months	12 months falls history	Not given	(R) Current knee pain 48% vs. no pain 30%
Menz et al 2006	Cohort	Community (AU)	N = 176 80.1 ± 6.4 years 68.1% female 21.6% had 'disabling' foot pain. Remainder had no foot pain, but other conditions such as osteoarthritis were present in some. Fallers 81.4 ± 6.4 years vs. non fallers 79.1 ± 6.3 years (*p*=0.022)	Manchester Foot Pain and Disability Index (MFPDI), which required participants to have current pain, to have pain lasting for at least 1 month	(P) 12 months	Monthly falls calendars for 12 months with follow up telephone calls for non-returners	Tinnetti et al 1988 [47]	(P) Foot pain 60.5% vs. no pain 27.7%

Supplemental Table S1 Summary of included studies

Study	Design	Setting	Participant information	Pain ascertainment location severity	Falls reference period	Mode of falls assessment	Definition of falls	Prevalence of Falls (1≥ falls)
Mickle et al 2010	Cohort	Community (AU)	N = 312 49.3% female 50% had foot pain 50% no foot pain, comorbid problems not mentioned. Fallers 71.6 years (CI = 70.4–72.9) Non fallers 71.2 years (CI = 70.3–72.2) (ns) 54% Fallers female 46.4% non-fallers female (ns)	Manchester Foot Pain and Disability Index. Duration & severity unknown	(P) 12 months	Monthly falls calendars for 12 months	Tinnetti et al 1998 [47]	(P) Foot pain 57.9% vs. no pain 42.1%
Morris et al 2004	Cross-sectional (baseline data)	Community (AU)	N = 1000 73.4 (65-94 range) 53.3% female Unclear number of participants who had chronic pain (12> months) Excluded for cognitive impairment or serious illness.	Pain frequency measured 5 point Likert scale (never to everyday) over past 12 months	(R) 12 months	Face to face interviews falls history over past 12 months	Not given	Not given

Supplemental Table S1 Summary of included studies

Study	Design	Setting	Participant information	Pain ascertainment location severity	Falls reference period	Mode of falls assessment	Definition of falls	Prevalence of Falls (1≥ falls)
Muraki et al 2011	Cross-sectional	Community (JP)	N = 1675 Male ages in years Non fallers 66.4 ± 11.7 Single fallers 67.6 ± 11.9 Multiple fallers 64.6 ±11.3 (ns) Female ages in years: Non fallers 64.4 ± 12.1 Single fallers 64.3 ± 12.2 Multiple fallers 69.1 ± 10.4 (p= 0.004) 64.9% of total sample female 24.4% had chronic knee pain (over past 12 months) 20.1% chronic LBP OA knee higher in females (p<0.05) Female multiple fallers more likely to have OA knee (p= 0.0002), males (ns). No comorbidities measured.	Assessment by orthopaedic doctor. Asked if had pain on most days in past year in hip and lower back.	(R) 12 months	Interview by doctor obtaining 12 months falls history.	Tinnetti et al [47]	Not given

Supplemental Table S1 Summary of included studies

Study	Design	Setting	Participant information	Pain ascertainment location severity	Falls reference period	Mode of falls assessment	Definition of falls	Prevalence of Falls (1> falls)
Nahit et al 1998	Case-controlled study	Community (UK)	N = 361 N = 111 with new episode of musculoskeletal hip pain median age = 66, IQR 56–72 years 68% female N = 251 age and gender matched controls with no hip pain in previous 12 months.	Attendees at GP for musculoskeletal hip pain. No prior hip pain in past 12 months	(R) 12 months	Questionnaire falls history past 12 months	Not given	(R) Hip pain 30.2% vs. no pain 20.2%
Nevitt et al 1989	Cohort study	Community (USA)	N = 325 83.1% female 60> years, mean ages not available. All had reported at least one fall in past 12 months. N = 32 had hip or knee pain No difference in gender between falls vs. no falls group.	Underwent doctor examination and had hip and/ knee pain on passive movement.	(P) 12 months	Weekly postcards for 12 months & telephone calls for non-returners	"Falling all the way down to the floor or ground, or falling and hitting an object like a chair or stair." No reference	Not given

Supplemental Table S1 Summary of included studies

Study	Design	Setting	Participant information	Pain ascertainment location severity	Falls reference period	Mode of falls assessment	Definition of falls	Prevalence of Falls (1≥ falls)
Sturnieks et al 2004	Cross-sectional	Community (AU)	N = 679 participants N = 283 arthritis (41.3%): 80.2 ± 4.3 years 74.6% female N = 401 no arthritis: 80.0 ± 4.6 years (ns) 58.6% female ($p<0.05$) N = 231 had pain N = 416 no pain N = 32 not available	Asked SF 12 question in last 4 weeks have you had pain interfering with activity. N = 106 a little pain N = 71moderate N = 51 quite a lot N = 3 unclear if those with pain had arthritis or not.	(R) 12 month	Falls history	Gibson et al 1987 [46]	(R)Pain intensity falls rate: A bit 45.7% Moderate 47.8% Quite a lot 62.7% A lot 100% No pain 39.4%
Tromp et al 1998	Cross-sectional	Community (NL)	N = 1469 72.6 ± 5.2 years 52.0% female Unclear how many participants had pain. Presence of chronic diseases assessed and analysed, including COPD, cardiovascular disease, stroke, urinary incontinence, diabetes mellitus, joint disorders, and malignant	Nottingham health profile used for pain. Unknown location or duration for pain	(R) 12 months	12 months falls history	Gibson et al 1987 [46]	Not given

Supplemental Table S1 Summary of included studies

Study	Design	Setting	Participant information	Pain ascertainment location severity	Falls reference period	Mode of falls assessment	Definition of falls	Prevalence of Falls (1> falls)
			neoplasms. Assessment of distance vision and hearing.					
Woo et al 2009	Cohort	Community (HK)	N = 4,000 72.49 ± 5.18 years 50.0% female Average age male groups 72.4 ± 4.9 years. Non-significant difference between any of the pain groups (including no pain). Average age female groups 72.7 ± 4.8 years. Non-significant difference between any of the pain groups (including no pain). Chronic diseases added as covariate.	Participants were asked about the presence of hip, knee and back pain over the past 12 months. Respondents could indicate: 0 Never 1. Rarely 2. Some of the time 3. Most of the time 4. All of the time (3&4 classified as chronic pain).	(P) 4 years (R) 12 months	(P) Participants were asked to record falls as they happened and they were contacted by telephone every 4 months for results over 4 years. Retrospective: 12 months recall of falls at five year follow up.	''A fall was defined as any unexpected loss of balance resulting in coming to rest on the ground.' No reference.	(P) 44% with chronic pain (mixed body sites) fell. 31.9% with no pain fell.

Supplemental Table S1 Summary of included studies

Study	Design	Setting	Participant information	Pain ascertainment location severity	Falls reference period	Mode of falls assessment	Definition of falls	Prevalence of Falls (1≥ falls)
Yagci et al 2007	Cross-sectional	Community (TR)	N = 240 61.52 ± 8.2 years 45.0% female N = 163 with pain Excluded for musculoskeletal injury or psychiatric disorder.	Asked if had musculoskeletal pain in lower body in past 6 months. Average pain intensity over past 6 months scored VAS 0-10	(R) 12 months	Falls history in past 12 months	'An incident that resulted in the person unexpectedly coming to the ground'. No reference given	Not given

Key

NS = non-significant, (R) = retrospective falls ascertainment, (P) = prospective falls ascertainment, VAS = visual analogue scale, OA = osteoarthritis, RA = rheumatoid arthritis, SF 12 = short form 12, SF 36 = long form 36, COPD = chronic obstructive pulmonary disease, IQR = interquartile range, WOMAC = Western Ontario and McMaster Universities Arthritis Index, GP = general practitioner, MFPDI = Manchester Foot Pain and Disability Index, LBP = low back pain, OR = odds ratio, CI = confidence Interval, NRS = numerical rating scale, AU = Australia, CN = China, HK = Hong Kong, IT = Italy, JP = Japan, NGA = Nigeria, NL = Netherlands, TH = Thailand, TR = Turkey, TW = Taiwan, UK = United Kingdom, USA = United Stated of America.

Methodological Quality of Included Studies – Newcastle Ottowa Scale (NOS)

Case Controlled Studies

Study	**Selection**				**Comparability**		**Exposure**			**Score**
	Patient definition	Representativeness of patients	Selection of controls	Definition of controls	Age	Gender or co-morbidity	Ascertainment of falls ¥	Same method for case controls	Non response rate	Total
Chaiwanichsiri et al 2009	MET	MET	MET	MET	MET	MET	UNCLEAR	MET	UNMENT	7
Dai et al 2012	MET	MET	MET	MET	MET	UNMET	UNCLEAR	MET	UNCLEAR	6
Levinger et al 2011	MET	UNCLEAR	MET	MET	MET	MET	UNCLEAR	MET	UNMET	6
Muraki et al 2011	MET	MET	MET	MET	MET	UNCLEAR	MET	MET	UNCLEAR	7
Nahit et al 1998	MET	MET	MET	MET	MET	UNCLEAR	UNCLEAR	MET	UNMET	6
Sturneiks et al 2004	MET	UNCLEAR	MET	MET	MET	UNCLEAR	MET	MET	UNMET	6
Yagci et al 2007	MET	UNMET	MET	MET	MET	UNCLEAR	MET	MET	UNMET	6

Key:

¥ Met was only given when studies provided a definition of falls and ascertained falls through a valid measure.

Methodological Quality of Included Studies – Newcastle Ottowa Scale (NOS)

Cohort Studies

Study	**Selection**				**Comparability**		**Outcome**			**Score**
	Representativeness of patients	Selection of controls	Ascertainment of exposure	Demonstration outcome of interest was not present at start of study	Age	Gender or co-morbidity	Ascertainment of falls ¥	Was follow up long enough	Adequacy of follow up	Total
Arden et al 1999	MET	MET	MET	UNMET	MET	UNCLEAR	UNCLEAR	MET	UNCLEAR	5
Arden et al 2006	MET	MET	MET	UNCLEAR	MET	MET	UNCLEAR	MET	MET	7
Bekibele & Gureje 2010	MET	MET	UNCLEAR	UNMET	MET	MET	UNMET	MET	MET	6
Blyth et al 2007	MET	MET	MET	UNMET	MET	MET	UNCLEAR	MET	MET	7
Cecchi et al 2009	MET	MET	MET	UNCLEAR	MET	UNCLEAR	MET	MET	UNMET	6
Kwan et al 2013	MET	MET	MET	UNMET	UNCLEAR	UNCLEAR	MET	MET	MET	6
Leveille et al 2002	MET	MET	MET	UNMET	MET	MET	MET	MET	MET	8
Leveille et al 2009	MET	MET	MET	UNMET	MET	MET	MET	MET	MET	8

Methodological Quality of Included Studies – Newcastle Ottowa Scale (NOS)

Menz et al 2006	MET	MET	MET	UNMET	MET	UNMET	MET	MET	UNMET	6
Mickle et al 2010	MET	MET	MET	UNMET	MET	UNCLEAR	MET	MET	MET	7
Morris et al 2004	MET	MET	MET	UNMET	MET	MET	UNCLEAR	MET	MET	7
Nevitt et al 1989	MET	UNMET	MET	UNMET	MET	MET	UNCLEAR	MET	MET	6
Tromp et al 1998	MET	MET	MET	UNMET	MET	MET	MET	MET	MET	8
Woo et al 2009	MET	MET	MET	UNMET	MET	MET	UNCLEAR	MET	MET	7

Key:

¥ Met was only given when studies provided a definition of falls and ascertained falls through a valid measure.