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

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Archives of Physical Medicine and Rehabilitation**Pain and the risk for falls in community dwelling older adults:****A systematic review and Meta-analysis**

Running title: Falls in older adults with chronic pain

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Conflict of Interest

None to declare by any author

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

ACCEPTED MANUSCRIPT

28 **Abstract**

29 Objective

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

32 Data Sources

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

35 Study Selection

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

42 Data extraction

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

44 Data synthesis

45 1,334 articles were screened and 21 studies met the eligibility criteria. 50.5% of older adults with
46 pain reported one or more fall over 12 months compared to 25.7% of controls ($p<0.001$). A global
47 meta-analysis with 14 studies ($n=17,926$) demonstrated that pain was associated with an increased
48 odds of falling (OR: 1.56, 95% Confidence Interval (CI): 1.36 to 1.79, $I^2=53\%$). A subgroup meta-
49 analysis incorporating studies that monitored falls prospectively established that the odds of falling

50 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
51 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;
52 OR 1.80, CI: 1.56 to 2.09, $I^2=0\%$).

53 Conclusion

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

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

58 **Abbreviations**

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

60 OR – odds ratio

61 RaR - rate ratio

62 CI – Confidence interval (all reported at 95%)

63 NOS – Newcastle Ottawa Scale

64 RCT - randomised controlled trials

65

66 Falls are a leading cause of unintentional injury and death in older age¹⁻² and can also result
67 in impaired mobility, disability, fear of falling and reduced quality of life³⁻⁶. In addition, falls are very
68 costly to health and social care systems⁷. Unsurprisingly, the prevention of falls in older adults is a
69 public health priority in many countries across the world⁸⁻¹⁰. A key component in preventing falls is
70 the identification of important factors that may increase the risk of falls^{4, 9, 11}. However, the 'gold
71 standard' multifactorial interventions to reduce falls have had relatively limited success¹¹, which
72 may be because some important risk factors remain elusive⁶. One important and potentially
73 significant risk factor that appears to be continually overlooked is pain^{6, 12-13}. For example, the
74 American and British Geriatric Societies¹⁴ provide detailed guidance on the assessment of
75 individuals at risk of falls but there is no specific mention of the assessment of pain or its importance
76 as a falls risk factor. This is surprising for a number of reasons. Firstly, pain is associated with mobility
77 deficits, impaired gait and balance deficits, all of which are well established internal risk factors for
78 falls^{4, 6, 12, 15-16}. Secondly, pain is very common in older people, with up to 76% of older people in the
79 community experiencing it¹⁷.

80 It is likely that pain has not been identified as a risk factor for falls due to the relative dearth
81 of research specifically investigating the association of pain and falls in older people⁶. Whilst there
82 has been comparatively few authors primarily investigating this, in 1999 Arden and colleagues¹⁸
83 demonstrated that the presence of severe chronic knee pain was associated with a 50% increased
84 risk of multiple falls. More recently, Leveille and colleagues⁶ also established that chronic pain was
85 associated with a significantly increased risk of falls. A recent review² investigated 31 common risk
86 factors for falls in community dwelling older adults did provide some consideration of the influence
87 of pain with falls. The authors established that pain (yes/ no) was associated with an increased risk
88 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%:
89 1.44 to 1.78). However, the results were overshadowed by a focus on other risk factors. Whilst this

90 review provides a useful insight, its generic focus means that it was not able to provide a detailed
91 exploration of the association of pain and falls and this is warranted.

92 Studies that explore the association between pain and the risk of falling offer valuable
93 information for clinicians working with older people. In order to address this we set out to conduct a
94 systematic review of studies investigating the association between pain and falls. . Previous research
95 ^{6, 13, 18} has suggested that certain sites and duration (e.g. chronic) of pain may heighten the risk for
96 falls. Therefore, wherever possible we will establish details of the site, location and duration of pain
97 and the influence of these on the risk of falls. A number of authors ^{4, 8, 19-20} have emphasised the
98 importance of developing a common taxonomy when reporting falls within trials to enable
99 replication and comparison. In order to address this, we will also establish current definitions
100 employed and methods of ascertaining falls within the literature. The primary aim of this systematic
101 review and meta-analysis is to establish if pain is associated with increased odds of falling in
102 community dwelling older people.

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114 **Methods**

115 The study is reported in accordance with the Preferred Reporting Items for Systematic Reviews and
116 Meta-analysis statement (PRISMA) ²¹.

117 *Eligibility criteria*

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

134 *Information Sources*

135 A systematic review of the literature was conducted according to the general guidance provided by
136 Cochrane reviewer's handbook²⁴. Major electronic databases were searched from inception until 1st
137 March 2013, including the Cochrane Library, CINAHL, EBSCO, EMBASE, PubMed and PsycINFO.
138 Online searches of key journals were conducted including the 'in press' sections of the Journal of the
139 American Geriatrics Society, Archives of Physical Medicine and Rehabilitation and Age and Ageing.
140 In addition the reference lists of relevant recent systematic reviews were also reviewed.

141 *Systematic Search Strategy*

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

148 *Study Selection*

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

155 *Data Collection*

156 Data extraction was initially conducted by one reviewer (BS) and independently validated by a
157 second reviewer (TB). The data extracted from each article included: year of publication, design,
158 sample size, participant information (age, % females, comorbidity), method of pain assessment,

159 location/duration/severity of pain, fall definition, method of falls ascertainment and number of
160 fallers (one or more falls in a set time period) in the pain and control samples. Wherever possible we
161 also extracted any reported association statistics (e.g. odds ratio (OR), rate ratio (RaR) etc.)
162 investigating the relationship between pain and falls together with 95% confidence interval (CI),
163 standard error and p value. If association statistics were not available, we extracted the raw data
164 and calculated the unadjusted odds ratio with a 2 X 2 table (together with a 95% CI and p value for
165 each analysis). These results will be hereafter described as 'unadjusted odd ratios based on raw
166 data'.

167 *Methodological and Risk of Bias Assessment*

168 Two reviewers (BS/TB) independently completed the methodological assessment of included articles
169 using the Newcastle Ottawa Scale (NOS)²⁵. The NOS provides an assessment of the quality of non-
170 randomised controlled trials and its content validity and reliability have been established²⁵.
171 Included studies are judged across three key areas: selection, comparability and outcomes. The NOS
172 provides an overall score for methodological quality of up to 9 stars and scores of 5 and above are
173 considered of satisfactory quality²⁶. The NOS provides pre-defined scoring criteria, but can be
174 further specified for the topic of study. We adapted the NOS to provide one star accounting for age
175 and another for gender or comorbidity when considering the comparability of included studies. In
176 addition, we updated the requirements for a star when considering the ascertainment of falls in the
177 exposure category.

178 *Summary measures*

179 Whenever possible we extracted association statistics (together with 95% CI and p value)
180 investigating the relationship between pain and falls, together with any adjusted confounding
181 factors. In addition, we extracted the raw data from each study to establish an unadjusted OR for
182 the association between pain and falls in a 2 X 2 table. If necessary 2 X 3 or 2 X 4 study designs were

183 pooled to generate a 2 X 2 table. If the raw data was not available we attempted to contact the
184 primary authors up to three times to enable inclusion in the meta-analysis.

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

188 *Data Synthesis*

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

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

206 *Outline of Results*

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

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229 **Results**230 *Study Selection*

231 The original electronic search produced 1334 hits and 10 additional articles were found from other
232 sources. After the removal of duplicates, 795 abstracts were examined and 69 articles were
233 considered in the full text review. At this stage, we contacted 13 authors requesting additional
234 information and 4 of these were subsequently included in the review³⁰⁻³³. In total, 48 articles were
235 excluded with reasons and 21 studies were included in the narrative review^{5-6, 12-13, 18, 30-45} and 14 of
236 these^{5-6, 12, 33-36, 38, 40-42} (n=17,926) were included in the meta-analysis. The search strategy is
237 presented in Figure 1.

238

*Insert Figure 1 about here*239 *Study and participant characteristics*

240 The summary of the 21 included studies is presented in Supplemental Table 1 (available online).
241 Seven studies had a case-control design^{13, 30, 32-36} and 14 were cohort studies^{5-6, 12, 18, 31, 37-45}. The
242 sample sizes in each study varied considerably, Arden et al³⁷ was the largest and included 6,441
243 older adults with 1,427 of those reporting prevalent knee pain, whilst Levinger et al³⁰ was the
244 smallest and included 62 older adults with 35 experiencing knee pain. The method of ascertaining
245 pain and the location and duration varied considerably in each study and is summarised in
246 Supplemental Table 1. Data on the mean age and gender for two comparative groups (either (a) the
247 pain/ no pain group or (b) fallers/ non fallers), were only available for 13 of the included studies<sup>6, 12-
248 13, 30-31, 33-35, 37-38, 40-42</sup> and is presented in Supplemental Table 1. There was considerable inconsistency
249 and heterogeneity in the reporting of comorbidities in each study, with few studies providing clear
250 information on this, but wherever available these are presented in Supplemental Table 1.

251 *Definition and ascertainment of falls*

252 Nine studies did not provide a definition for a fall^{12, 18, 30, 34-38, 43}. Seven studies provided a definition
253 for a fall referenced by the literature and the most common was that offered by the Kellogg
254 International working group⁴⁶ (n=4)^{5-6, 33, 45} and the definition offered by Tinetti⁴⁷ (n=3)^{13, 41-42}
255 whilst a further 5 studies offered a definition, but this was not referenced by the literature^{31-32, 39-40},
256⁴⁴ see Supplemental Table 1.

257 *Prevalence of falls reported by older adults with and without pain*

258 We calculated the mean percentage of fallers (one or more fall) over 12 months for the older adults
259 with and without pain utilising the raw data from 12 studies^{5, 12, 30-33, 35-36, 38, 40-42} with the data from
260 the 2 X 2 tables. This established that 50.5% of older adults with pain reported one or more fall over
261 12 months compared to 25.76% of the control group (p<0.001).

262 *Association between pain and falls in the individual studies*

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

267 *Insert Table 1 about here*

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

272

273 *Meta-analysis of Overall Odds of falling*

274 A global meta-analysis was conducted with 14 studies^{5-6, 12, 30-36, 38, 40-42} (n= 17,926: 5,825 with pain
275 and 12,101 without pain) and established that pain was associated with a 56% increased odds of
276 falling (OR: 1.56, CI: 1.36 to 1.79, $p < 0.0001$). The data was heterogeneous ($I^2 = 52%$, $p < 0.05$, see
277 Figure 2a. A visual inspection of a funnel plot established one study³² was at risk of publication bias
278 and was subsequently excluded from all further subgroup analysis²⁴ (see Figure 2b.)

279

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

281 A meta-analysis with the five studies^{5-6, 31, 41-42} (n=4,674) that collected falls data prospectively,
282 established that older adults with pain had an increased odds of falling by 71% (OR: 1.71, CI: 1.48 to
283 1.98, $p < 0.0001$). The data was homogenous ($I^2 = 0%$, $p = 0.5$). A subgroup analysis was conducted with
284 nine studies^{12, 30, 32-36, 38, 40} (n=13,012) that collected falls data retrospectively and this established the
285 odds of falling was increased by 43% (OR: 1.43, CI: 1.22 to 1.69, $p < 0.0001$). This subgroup analysis
286 was heterogeneous ($I^2 = 49%$, $p < 0.05$), see figure 3.

287

Insert figure 3 about here

288 *Different pain locations and association with falls.*

289 The results of studies looking at single sites of pain and the association with falls showed
290 inconsistent results. For instance, only 2 of the 6 studies that examined falls in people with hip pain
291 found a significantly increased risk for falls^{18, 44}. Three out of six studies established that knee pain
292 demonstrated an increased falls risk^{13, 37, 40}, but 1 study found that this risk was only increased in
293 those multiple fallers¹³. Similarly, three out of five studies^{13, 38, 43} demonstrated that back/ neck pain
294 was associated with falls and two found the risk was particularly increased for multiple falls^{13, 43}.
295 Three out of four studies established that foot pain was associated with an increased risk of falls
296 ranging from 87% and 260%^{34, 42-43}. When looking at 'body pain' of an undefined location or mixed
297 pain sites, 6 studies^{5, 31-32, 38, 43, 45} out of seven demonstrated that pain was associated with an

298 increased risk of falls. It was possible to calculate the unadjusted OR calculated for two of these
299 studies^{5, 38} and it was within 6% from that reported in the adjusted association reported in each
300 paper. Finally, both studies^{6, 12} investigating multisite/ widespread pain established an increased risk
301 of falls. The adjusted association statistics and unadjusted OR calculated from the raw data are
302 presented in Table 1.

303 *Meta-analysis of falls risk according to location of pain*

304 A subgroup meta-analysis with 3 studies^{34, 41-42} (n=691) found that foot pain was associated with a
305 138% increased odds of falling (OR: 2.38, CI: 1.62 to 3.48, $p < 0.0001$). The data was homogeneous
306 ($I^2=8%$, $p=0.33$). A subgroup meta-analysis with 3 studies^{31, 36, 40} (n=2,786) established hip pain was
307 associated with a 36% increased odds of falling (OR: 1.36, CI: 1.00 to 1.84, $p=0.05$). The data was
308 homogenous ($I^2=0%$, $p=0.67$). A subgroup analysis with 3 studies^{30-31, 40} (n=2,634) did not establish a
309 significant relationship between knee pain and falls whilst a subgroup analysis of 'other' types of
310 pain with 5 studies^{5-6, 12, 31, 38} (total n =6,397) established a 54% increased odds of falling (OR: 1.54,
311 CI: 1.25 to 1.88, $p < 0.0001$, $I^2=58%$, $p < 0.05$). See Figure 4 for each meta-analysis.

312 *Insert Figure 4 about here*

313 *Pain severity*

314 Each of the 3 studies^{6, 33, 39} that investigated the relationship between pain severity and falls
315 established that the risk of falls was higher as pain severity and its interference with activities
316 increased.

317 *Chronic Pain*

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

320

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

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

327 *Insert Figure 5 about here*

328 *Meta-regression*

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

332 *Methodological Quality Assessment*

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

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339

340 **Discussion**

341 The present study involving over 17,000 older adults is to our knowledge the first systematic
342 review and meta-analysis focussing on the association between pain and falls in community dwelling

343 older adults. The global meta-analysis established that pain was associated with a 56% increased
344 odds of falling. We conducted a number of subgroup analyses (according to method of falls
345 ascertainment, location of pain and duration of pain) and consistently found that pain was
346 associated with increased odds of falling. In addition, all of the 12 studies within the narrative
347 review which reported an adjusted association statistic, demonstrated that pain was associated with
348 increased risk of falling. This review also demonstrated that 50.5% of older adults with pain reported
349 one or more falls over 12 months compared to 25.7% of the control group ($p < 0.001$). This figure of
350 falls is considerably higher than the 30% of community dwelling older adults that fall each year^{4, 48-}
351⁴⁹.

352 A subgroup meta-analysis utilising prospective falls data established that the odds of falling
353 were increased by over 70% for those with pain. Ascertaining falls with prospective measurement is
354 regarded more accurate than retrospective recall, although there is still some debate around the
355 optimal method to monitor falls^{8, 50-51}. The data from this analysis was homogenous ($I^2 = 0\%$) and for
356 these reasons it may represent the most accurate association between pain and falls from all of our
357 analyses. Our subgroup meta-analysis investigating the association between pain and falls recorded
358 retrospectively ($n = 13,012$) established a more moderate association with falling (OR: 1.43, CI: 1.22 to
359 1.69,) which is not surprising as the retrospective recall of falls is often under reported⁵²⁻⁵³.

360 A previous review² only utilised prospective falls data to avoid reverse causality, which is
361 clearly a consideration for our results where falls were obtained retrospectively. However, we
362 attempted to negate this by excluding studies where participant's pain was identified from a
363 previous fall. Retrospective recall of falls over 12 months is relatively specific (91-95%) although less
364 sensitive than prospective measurement of falls⁵¹. The result that older adults with pain are 43%
365 more likely to have fallen in the past year is important, since a history of falls is strongly associated
366 with future falls^{1-2, 51} and is commonly advocated as a valid indicator/ assessment in clinical practice
367¹⁴.

368 We set out to establish if the location and duration of pain is associated with differing risks
369 of falling since this information would provide valuable information to clinicians. Our meta-analysis
370 established that foot pain was strongly associated with falls (n=691, OR: 2.38, CI: 1.62 to 3.4). We
371 also established that hip pain was associated with falls (n=2,786, OR 1.36, CI: 1.00 to 1.84) which is in
372 line with the adjusted association statistics reported from large cohort studies which established an
373 increased risk when falls are measured retrospectively¹⁸ or prospectively⁴⁴. Our sub group analysis
374 with older reporting knee pain (n=2,634) established that knee pain was not associated with falls.
375 However, several individual studies reported knee pain is associated with an increased risk of falls
376 when the pain is severe³⁷ or chronic¹³. We conducted an analysis of pain classified as 'other' (any
377 bodily pain or non-knee, foot, hip or spinal pain) and found a pronounced increased odds of falling
378 (OR: 1.54, CI: 1.25 to 1.88), but this data was heterogeneous. Finally, our subgroup meta-analysis
379 with 5,367 older adults established that chronic pain was associated with increased odds of falling by
380 80% (OR 1.80, CI: 1.56 to 2.09, $I^2=0\%$). This is in line with Leveille and colleagues'⁶ study who
381 demonstrated that chronic polyarticular pain was associated with a 70% increased risk of falling. We
382 also conducted an analysis for non-chronic pain and this established the odds of falling was
383 increased by 61% (OR: 1.61, CI: 1.39 to 1.86, $I^2 = 4\%$).

384 The underlying reasons for the association between pain and falls are likely to be
385 multifaceted, since pain in itself is a very complex phenomenon. Previous researchers⁶ have
386 postulated that the mechanisms by which chronic musculoskeletal pain increases the risk of falls
387 may be the result of three possible causes: 1) local joint pathology (e.g. osteoarthritis), 2) the
388 neuromuscular effects of pain and 3) central mechanisms, where pain interferes with the older
389 adult's cognition and executive function. Another factor that could possibly contribute is
390 psychological concerns related to falling (fear of falling, falls efficacy), since these are known to
391 increase the risk of falls in their own right² and are associated with pain⁵⁴. The strength of
392 association between foot pain and chronic pain with falls is higher than several commonly
393 considered risk factors such as cognitive impairment (OR 1.36, CI: 1.12 to 1.65, ²), depression (OR

394 1.63, CI: 1.36 to 1.94²), visual impairment (OR 1.35, CI: 1.18 to 1.54²) and the use of sedative
395 medication (OR 1.38, CI: 1.15 to 1.66)². The results for our meta-analysis were consistently higher
396 than the reported association between pain and falls reported in another review which only included
397 two studies in the faller's category². Our results suggest it is advisable that clinicians working within
398 rehabilitation of the older person at risk of falling should routinely assess pain, paying particular
399 attention to foot and chronic pain. In addition, clinicians working with older adults who present with
400 pain ought to routinely ask the patient about their history of falls, recognising they may be at
401 increased risk of future falls. Adequate pain management is likely to be very important in the older
402 person's rehabilitation and may serve to reduce the risk of falls. The strong association of foot pain
403 with falls advocates the importance of podiatrists within the rehabilitation multidisciplinary team to
404 prevent falls. Previous research has demonstrated that multifaceted interventions delivered by
405 podiatrists to older people with foot pain can have a reduction in the rate of falls which is
406 comparable to other well established interventions such as tai chi⁵⁵.

407 Within this study we encountered a wide range of association statistics being utilised
408 together with a plethora of adjustments for confounding factors making the meta-analysis very
409 difficult. We contacted numerous authors and relied upon the unadjusted OR from the raw data for
410 the meta-analysis. The use of adjusted OR are considered more reliable, however only considering
411 the adjusted OR may lead to an over estimation of the influence of pain on falls². We calculated the
412 unadjusted OR and observed small differences compared to the reported adjusted association
413 statistics in several instances^{5-6, 38}. In addition, all 12 studies included in the narrative review that
414 reported an adjusted association statistic established that pain increased the risk of falls.

415 Our review found 9 studies (43%) did not provide a definition for a fall, this is concerning but
416 consistent with previous research in the wider falls literature^{8, 19}. Standardisation in the definitions
417 employed within research is essential to enable replication and also to enhance quality of research
418 and enabling meta-analyses to be completed⁵³. The PROFANE European falls network¹⁹ offers an

419 excellent comprehensive falls taxonomy that ensures continuity and consistency in research
420 investigating falls. Most studies included within this review ascertained falls retrospectively, whilst
421 this is still insightful, documentation of falls prospectively does have advantages in terms of accuracy
422 and reducing concerns of reverse causality.

423 *Limitations*

424 It is important that a number of considerations are made when interpreting the results from
425 this review. First, it is not possible to rule out reverse causality for the meta-analysis that
426 incorporates the results of falls ascertained retrospectively. Second, the assessment and
427 classification of pain in each study varied considerably and future research should seek to unify the
428 way pain is defined and assessed and we have made recommendations for this elsewhere⁵⁶. Third,
429 we only conducted meta-analyses utilising unadjusted OR. In addition the information available on
430 mean age, gender and comorbidity in each study was limited and we could not consistently adjust
431 for these in each analysis. In order to explore the influence of age and gender on the observed
432 effects, we conducted numerous meta-regression analyses with these factors as moderators and
433 none reached statistical significance. In addition within each study, two reviewers independently
434 considered age, gender or comorbidity in the NOS. Age was met in all but one study whilst only 11
435 met the criteria for gender or comorbidity since the information was not clear in a further 8 studies.
436 Although we attempted to exclude certain comorbidities in our exclusion criteria (e.g. stroke,
437 dementia) it is possible that other comorbidities (e.g. osteoarthritis) were present among the study
438 populations and could have influenced the observed effects²³. We only conducted a review of the
439 methodological quality of included articles and did not conduct a specific risk of bias assessment.
440 This is now recommended by the Cochrane collaboration and may have affected the interpretation
441 of our results. In addition, we did not consider articles that were not written in English and we may
442 have missed some data. We also excluded studies conducted in individuals with dementia,
443 neurological conditions and recent orthopaedic trauma since this would have introduced further

444 heterogeneity in our sample and may have impacted the results. Finally, we did not consider single
445 and recurrent fallers separately and since this is an at risk group this warrants further exploration.

446 *Future research*

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

460 *Conclusions*

461 The results of this meta-analysis established that older adults with pain are at increased risk of falls.
462 We found that 50.5% older adults with pain reported one or more falls in a year compared to 25.7%
463 ($p < 0.001$) in those without pain. In addition, we found that foot pain and chronic pain were strongly
464 associated with falls in community dwelling older adults. Clinicians completing falls risk assessments
465 should routinely enquire about the older person's current pain and pay particular attention to foot
466 and chronic pain. There is a need for well-designed prospective epidemiological studies to further

467 establish this link which can inform future intervention studies to manage pain in older people which
 468 in turn may reduce the risk of falls in clinical practice.

469

470 **Conflict of Interest**

471 None to declare by any author

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616 **Figure listings**

617 Figure 1 – PRISMA search strategy

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

- 619 Figure 2b – funnel plot of included studies for global meta-analysis
- 620 Figure 3. Meta-analysis comparing falls data collected prospectively and retrospectively
- 621 Figure 4. Sub group Meta-analysis investigating location of pain and association with falls
- 622 Figure 5. Sub group Meta-analysis investigating the association of chronic and non-chronic pain with
- 623 Falls
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- 628

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)	Unadjusted † ‡
			2> fall OR 2.52 (CI: 1.58 to 4.02) 2> fall OR 1.61 (CI: 0.92 to 2.79)	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
<hr/>				
<i>Back/ Neck Pain</i>				
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* 2> Fall OR 3.90 (CI: 2.49 to 6.16) P<0.001*	Unadjusted Unadjusted
Muraki et al 2011	Chronic LBP	12 months (R)	1> fall OR 1.28 (CI: 0.82 to 1.96) 1> OR fall 1.34 (CI: 0.84 to 2.08) 1> fall OR 1.33 (CI: 0.84 to 2.08)	Unadjusted † ‡
Woo et al 2009	Chronic back pain	12 months (R)	2> fall OR 2.14 (CI: 1.30 to 3.46) 2> fall OR 1.72 (CI: 1.01 to 2.88) 2> fall OR 1.58 (CI: 0.91 to 2.70) OR 1.14 (0.85-1.51) p=0.3625	Unadjusted † ‡ 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
<i>Unspecified/ Any Body Pain</i>				
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: Pooled pain data of all types of pain	12 months (R)	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:	12 months (R)	OR 1.83 (1.33-2.53) p=0.000*	Raw data
	Single site		OR 1.57 (1.05 - 2.35) P = 0.0261*	Raw data
	Polyarticular		OR 2.01 (1.41 - 2.85) P = 0.0001*	Raw data
Leveille et al 2009	Single site pain	18 months (P)	RaR 1.19 (CI: 0.90 to 1.56)	Age, sex, education
	Polyarticular pain		RaR 1.70 (CI: 1.34 to 2.20)	
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)	<p><i>No interference</i></p> <p>1>fall PR 1.15 (CI: 0.97 to 1.37)</p> <p>2>PR 1.31 (CI: 0.92 to 1.86)</p> <p><i>Slight interference</i></p> <p>1>fall PR 1.37 (CI: 1.16 to 1.62) 0.0002*</p> <p>2>fall PR 1.66 (CI: 1.19 to 2.33) 0.0032*</p> <p><i>Moderate interference</i></p> <p>1>fall PR 1.72 (CI : 1.47 to 2.00) <0.0001*</p> <p>2> PR 2.29 (CI: 1.67 to 3.13) <0.0001*</p>	Age & Gender
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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

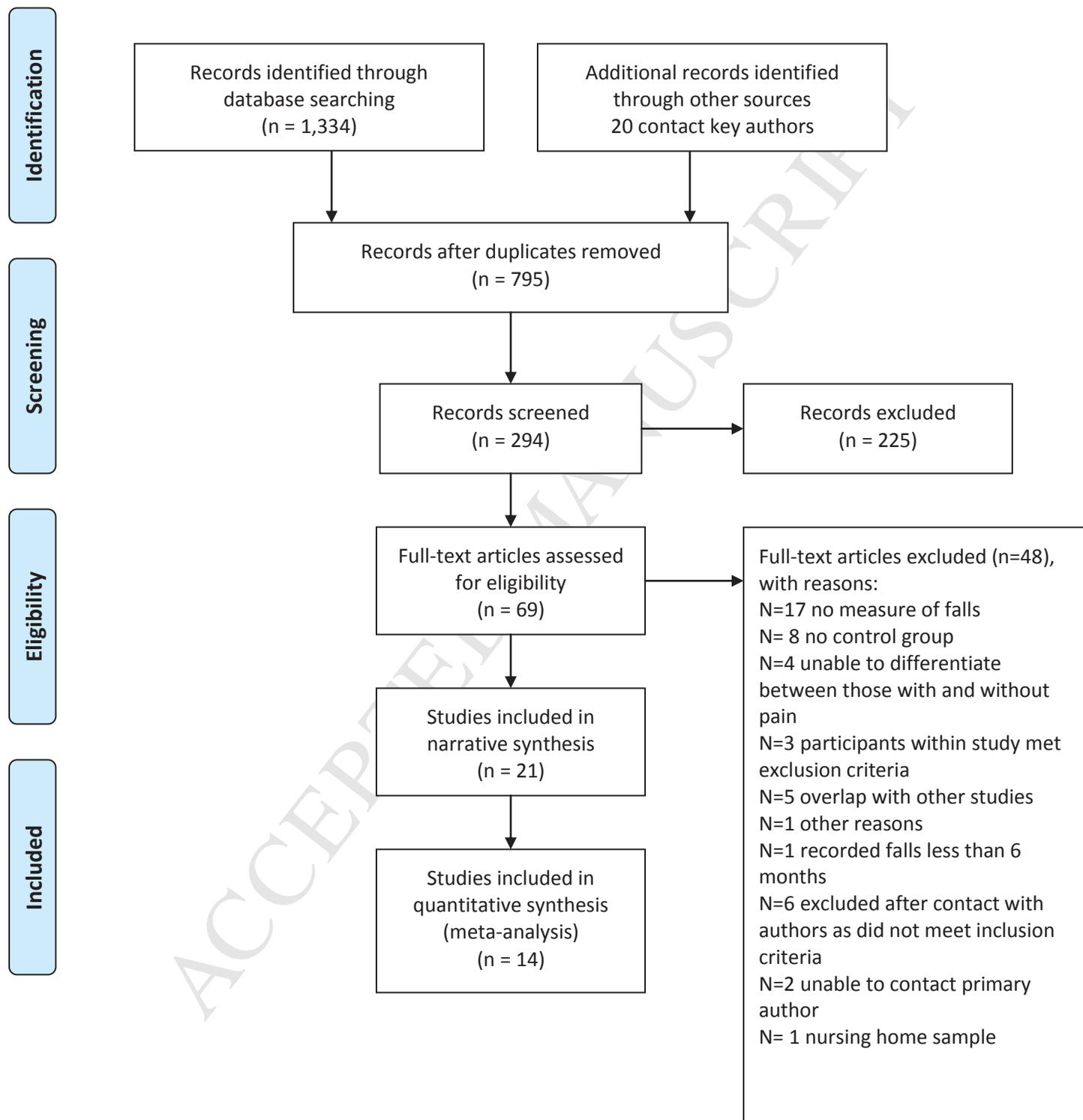


Figure 2a. Global Meta-analysis for all studies investigating the association of pain with falls (Online supplementary file)

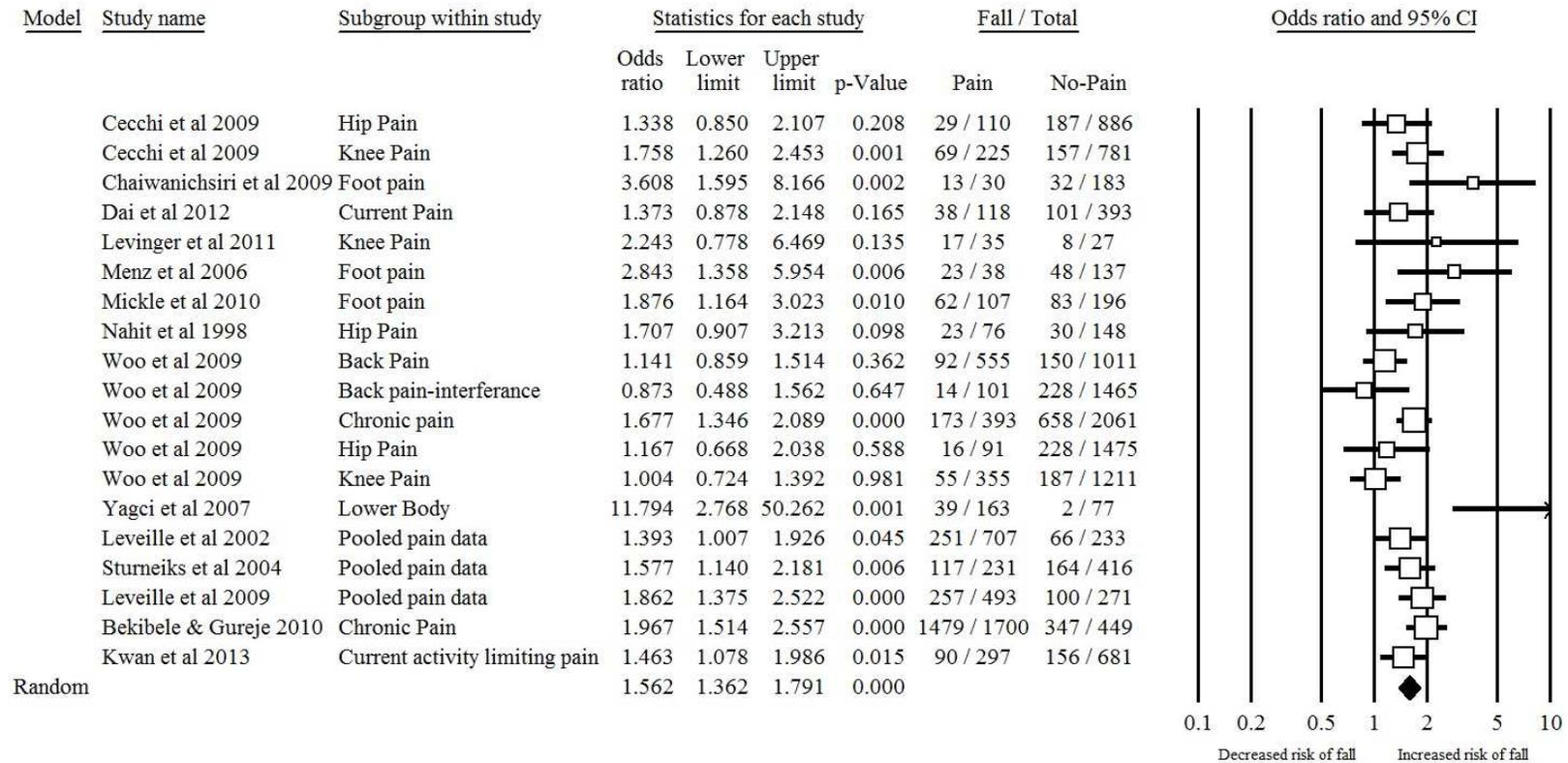


Figure 2b. Funnel plot to assess risk of bias in Global Meta-analysis

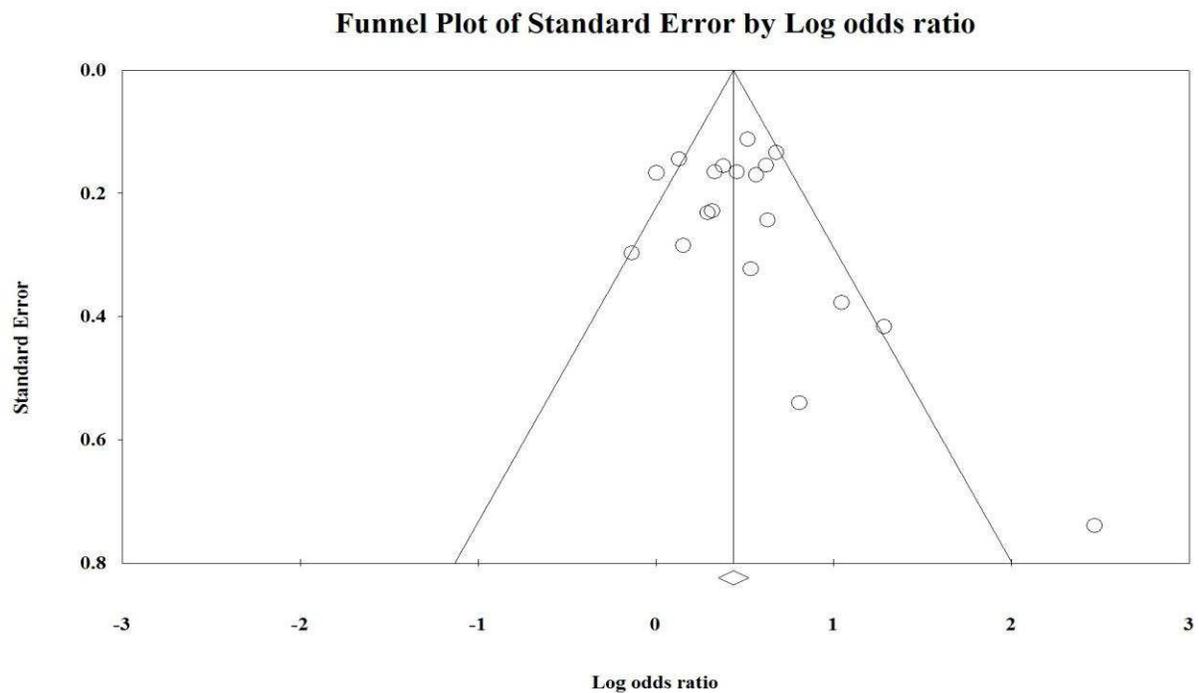


Figure 3. Meta-analysis comparing falls data collected prospectively and retrospectively

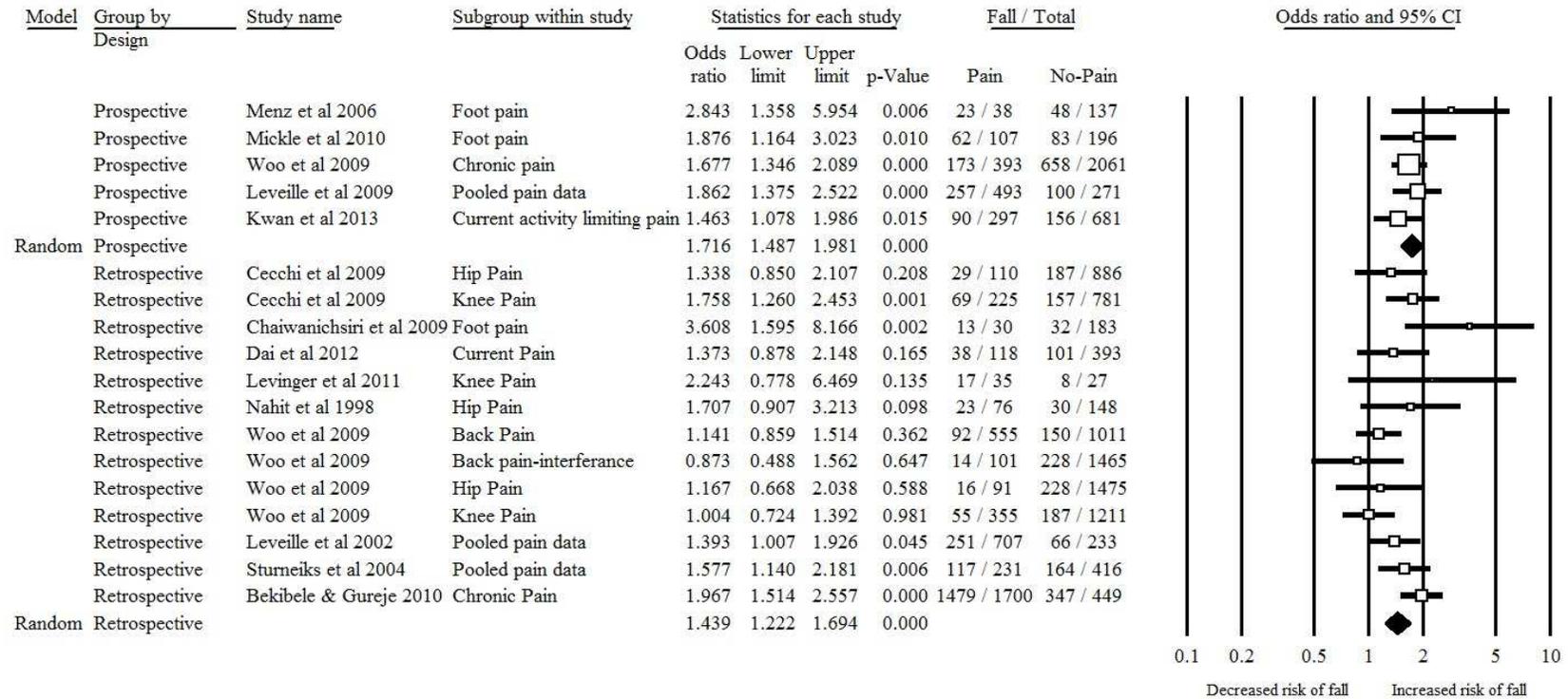


Figure 4. Sub group Meta-analysis investigating location of pain and association with falls

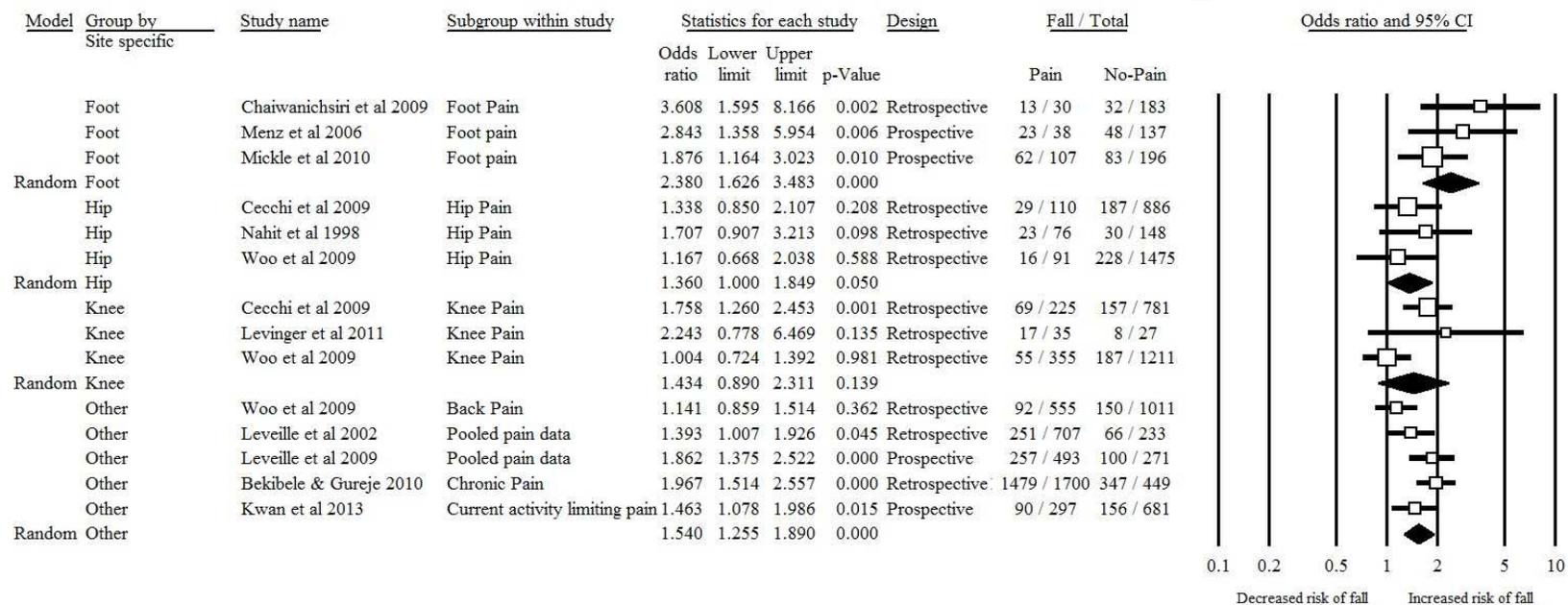
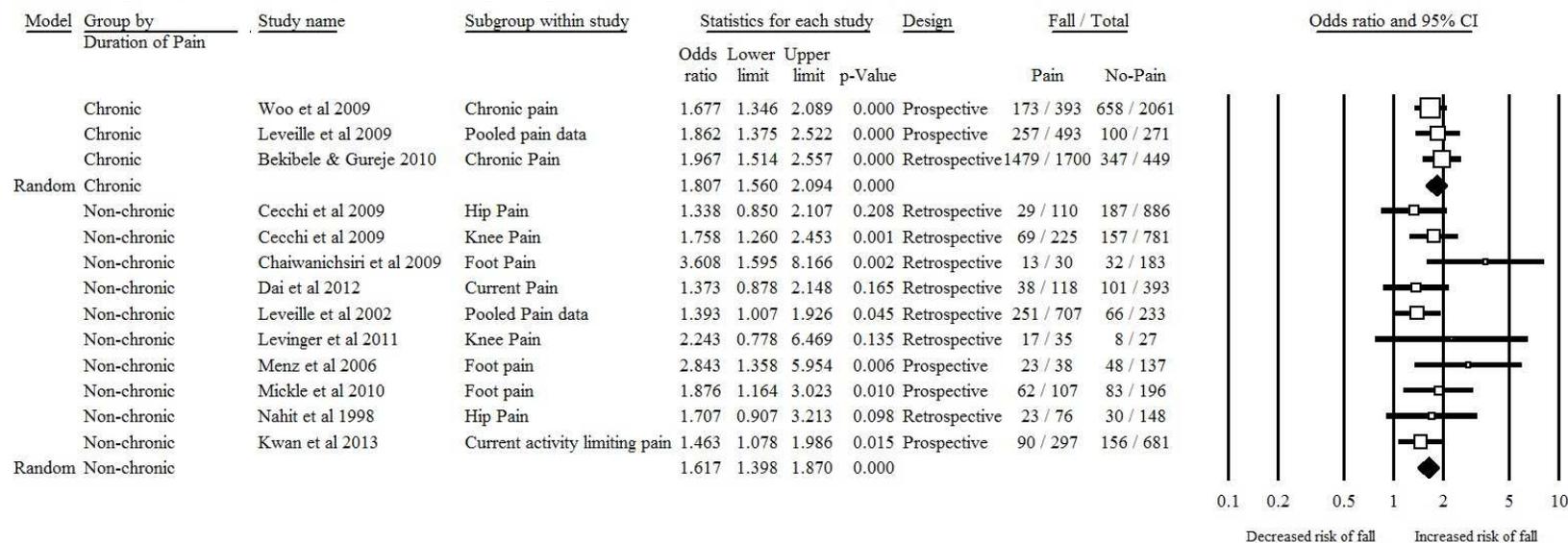


Figure 5. Sub group Meta-analysis investigating the association of chronic and non-chronic pain with



falls

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 ($1 \geq$ 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 ($1 \geq$ falls)
Cecchi et al 2009	Cohort	Community (IT)	<p>N = 1006 75.2 \pm 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 \pm 7.2 years No pain 75.2 \pm 7.1 years (ns)</p> <p>N = 225 with knee pain: Pain 74.3% females No pain 50.9% females ($p < 0.01$) Pain = 75.4 \pm 6.9 No pain = 75.2 \pm 7.2 (ns)</p> <p>Covariates: hypertension, peripheral artery diseases, stroke, cardiovascular disease and depression. Foot pain was present in 16-30% of participants.</p>	<p>Questionnaire literature 'over the past four weeks, did you ever experience hip/ knee pain?' Also completed WOMAC</p>	(R) 12 months	Questionnaire of if fallen $1 \geq$ times in past 12 months	'An incident resulting in the participant coming unexpectedly to the ground'. No reference	<p>(R) Hip pain 32.5% vs. no hip pain 21.1% $p = 0.027$</p> <p>(R) Knee pain 30.7% vs. no knee pain 20.1% $p = 0.01$</p>

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 ($1 \geq$ falls)
Chaiwanichsiri et al 2009	Cross-sectional	Community (TH)	<p>N = 213 68.6 ± 5.4 years 49.2% female N = 30 with foot pain</p> <p>Male: Fallers 70.2 ± 6.4 years Non fall 68.4 ± 5.0 years Significant $p < 0.001$</p> <p>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 ($p < 0.05$)</p>	Foot pain confirmed by physician. Duration/severity unknown	(R) 6 months	Interview history of falls	Not given	<p>(R) ≥ 1 Fall over 6 months Males with foot pain 7.1% vs. no pain 5.3%</p> <p>Females with foot pain 38.7% vs. no pain 16.2%</p>
Dai et al 2012	Cross-sectional	Community (USA)	<p>N = 511</p> <p>N = 372 non fall group: 71 ± 9.3 years 56.9% female</p> <p>N = 139 in fall group: 75 ± 11 years ($p < 0.01$) 68.3% female 23% had pain Excluded only if physician or</p>	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

tester regarded it unsafe

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)	<p>N = 1456</p> <p>N = 692 Chinese and Taiwanese: 74.9 ± 6.4 years 59.4% female</p> <p>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.</p>	<p>Questionnaire on current pain interfering with activity. No details on location & duration</p>	(P) 12-24 months	<p>Chinese sample: monthly telephone calls for 12-24 months. Australian white sample monthly falls calendars 12-24 months.</p>	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 (≥ falls)
Leveille et al 2002	Cohort	Community (USA)	<p>N = 1002 100% female</p> <p>N = 295 no pain N = 189 other pain N = 293 lower extremity pain N = 225 widespread pain</p> <p>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 (<i>p</i><0.001)</p> <p>OA of knee: No pain 12.9% Other pain 30.7% Lower extremity 49.8% widespread pain 49.3% (<i>p</i><0.001).</p> <p>OA of hip No pain 1.2%, Other pain 7.4% Lower extremity pain 11.6% Widespread pain 11.6%</p>	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	<p>(R) Other pain 35.5% (R) Lower extremity pain 31.9%</p> <p>(R) Widespread pain 40.4% vs. no pain 28.5%</p>

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)	<p>N = 748 All >70 years 63.2% female</p> <p>N = 267 no pain (35.6%) N = 181 single site pain (24.2%) N = 300 polyarticular pain (40.1%)</p> <p>OA at any site: No pain 11.6% Single site 35.9% Polyarticular 60.5% ($p<0.01$)</p> <p>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 ($p=0.008$).</p>	<p>13 item joint pain questionnaire to establish chronic pain in hands, wrist, shoulders, back, chest, hips, knees and feet. Chronic pain ≥ 3 months.</p>	<p>(R) 12 months & (P) up to 18 months</p>	<p>Retrospective 12 months falls history questionnaire. Prospective monthly falls calendars for up to 18 months and follow up telephone calls</p>	Gibson et al ⁴⁶	<p>(R) Single site pain 38.3% (R) Polyarticular pain 44.2% vs. no pain 28.3%</p>

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 ($1 \geq$ 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	Tinetti 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)	<p>N = 1675</p> <p>Male ages in years Non fallers 66.4 ± 11.7 Single fallers 67.6 ± 11.9 Multiple fallers 64.6 ± 11.3 (ns)</p> <p>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)</p> <p>64.9% of total sample female</p> <p>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.</p>	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-returns	"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 ($1 \geq$ falls)
Sturnieks et al 2004	Cross-sectional	Community (AU)	N = 679 participants N = 283 arthritis (41.3%): 80.2 \pm 4.3 years 74.6% female N = 401 no arthritis: 80.0 \pm 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 = 71 moderate N = 51 quite a lot N = 3 unclear if those with pain had arthritis or not.	(R) 12 months	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 \pm 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)
Woo et al 2009	Cohort	Community (HK)	<p>neoplasms. Assessment of distance vision and hearing.</p> <p>N = 4,000 72.49 ± 5.18 years 50.0% female</p> <p>Average age male groups 72.4 ± 4.9 years. Non-significant difference between any of the pain groups (including no pain).</p> <p>Average age female groups 72.7 ± 4.8 years. Non-significant difference between any of the pain groups (including no pain).</p> <p>Chronic diseases added as covariate.</p>	<p>Participants were asked about the presence of hip, knee and back pain over the past 12 months. Respondents could indicate:</p> <ol style="list-style-type: none"> 0 Never 1. Rarely 2. Some of the time 3. Most of the time 4. All of the time <p>(3&4 classified as chronic pain).</p>	<p>(P) 4 years (R) 12 months</p>	<p>(P) Participants were asked to record falls as they happened and they were contacted by telephone every 4 months for results over 4 years.</p> <p>Retrospective: 12 months recall of falls at five year follow up.</p>	<p>“A fall was defined as any unexpected loss of balance resulting in coming to rest on the ground.’ No reference.</p>	<p>(P) 44% with chronic pain (mixed body sites) fell. 31.9% with no pain fell.</p>

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 ($1 \geq$ falls)
Yagci et al 2007	Cross-sectional	Community (TR)	N = 240 61.52 \pm 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 States of America.

Methodological Quality of Included Studies – Newcastle Ottawa 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	
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 Ottawa 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.