Effects of Fall Prevention Programs for Older Adults on Fall-Related Injuries: A Systematic Review and Meta-Analysis

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Jung-Yu Liao

Abstract

This study aimed to evaluate the effects of fall prevention programs on fall-related injuries, and the characteristics of these programs. The Cochrane Library, Medline, PubMed, PsycARTICLES, PsycINFO, ERIC, AgeLine, CINAHL, Psychology and Behavioral Sciences Collection databases were searched for randomized clinical trials on fall-related injuries among older adults from 1996 to 2016. A meta-analysis was performed to calculate the combined effects of fall prevention programs on fall-related injuries. A total of 33 research papers were included in the meta-analysis (68,736 participants). The meta-analysis found that fall prevention programs had a significant effect in preventing fall-related injuries ($\text{OR}=0.86$, $95\% \text{ CI}: 0.75-0.97$), but a borderline-significant effect in preventing fractures ($\text{OR}=0.80$, $95\% \text{ CI}: 0.63-1.03$). The fall prevention programs had a significant effect on fall-related injuries when both male and female participants were included in the study sample, interventions involved healthcare professionals, more than 20% of the patient population had a history of falling, interventions occurred in the community setting, and multiple interventions were used. Thus, fall prevention programs had a small but significant effect in preventing fall-related injuries but only a borderline effect in preventing fractures. When planning fall prevention programs,
future policy makers and clinical workers should consider the different characteristics of older adults to propose appropriate intervention programs.

**Keywords**: accidental falls, fall prevention, injury, meta-analysis, older adults
Introduction

Every year, approximately 28%-35% of elderly people aged 65 years or older experience falls; for those older than 70 years, the incidence of falls increases to 32%-42% (World Health Organization, 2008). In the United States (U.S.), an estimated 3.2 million elderly individuals aged 65 years and above experienced falls annually, i.e., an incidence of 32.3%. From 2004 to 2013, the number of elderly women increased by 4% each year, with the incidence of falls being the highest in women above 75 years of age (Verma et al., 2016). Approximately 10%-31% of older adults who experience falls suffer from a fall-related injury annually (Alexander, Rivara, & Wolf, 1992; Gill, Murphy, Gahbauer, & Allore, 2013; Stevens, Mack, Paulozzi, & Ballesteros, 2008). It is similar in Taiwan that 21% of older adults experience falls in the past year and one third of them suffer from a fall-related injury (Ministry of Health and Welfare, 2014).

There are numerous factors that increase falls in the elderly, and many researchers have developed preventive strategies against various risk factors. Some studies have concluded that intervention programs are ineffective (Vind, Andersen, Pedersen, Jørgensen, & Schwarz, 2009), but results from meta-analyses have found that intervention programs can effectively reduce the incidence of falls in elderly people. Gillespie et al. (2009) found no significant decrease in the risk of falls and fractures after participants completed a fall prevention program. However, El-Khoury, Cassou, Charles, and Dargent-Molina (2013) found that fall prevention programs successfully reduced fall-related injuries. The findings of previous meta-analyses are inconsistent. In addition, Gillespie et al.’s’ study was published eight years ago, in 2009. Hence, there is a need to conduct another meta-analysis to explore the summary effects.

Currently, most meta-analyses have focused on analyzing the effectiveness of fall prevention programs for the elderly on the incidence of falls and recurrent falls. Few studies have analyzed the effects of fall prevention programs on fall-related injuries in the elderly.

In this study, the definition of fall-related injury included bruising, sprains, cuts, abrasions, as well as serious injuries, such as lacerations, skin lacerations requiring suturing, and head injuries (Baranzini et al., 2009; Elley et al., 2008). Fractures are both the most frequent and most expensive type of non-fatal injuries that occur (Stevens, Corso, Finkelstein, & Miller, 2006). This is a critical concern, as fractures not only increase the burden of care, but also incur large medical expenses (Hartholt et al., 2011; Hoffman, Hays, Shapiro, Wallace, & Ettner, 2017). Thus, we analyzed fractures and fall-related injuries separately. Here we conducted a meta-analysis to investigate the effectiveness of fall prevention programs for the older adults in preventing fall-related injuries.
Fall-related injuries were divided into two categories: overall injury and fractures.

**Methods**

**Literature search**

The study collected English language papers on fall prevention programs from 1996 to 2016. Electronic journal databases, including Cochrane Library, Medline, PubMed, PsycARTICLES, PsycINFO, ERIC, AgeLine, CINAHL, Psychology and Behavioral Sciences Collection databases were searched. The following Medical Subject Headings (MeSH) subject terms and keywords were used: “fall,” “elderly,” “injury,” “prevention program,” or “intervention.” Google Scholar was used as a supplement for these databases to search for possible omissions. Additionally, we reviewed the bibliography of collected articles to identify those that were missing from the electronic databases.

**Study selection**

The study eligibility criteria were as follows: (a) English language papers from 1996 to June, 2016; (b) studies with participants who were older adults aged 65 years and above; (c) studies with statistical data about injury due to falls after intervention; (d) randomized control trials (RCTs) on fall prevention interventions (with single or multiple interventions); and (e) used quantitative and statistical methods to calculate the effect size.

The exclusion criteria included: Lack of fall-related injury data, age <65 years, lack of quantitative data, not an RCT, not enough statistic value to calculate odds ratio (OR), and studies with the same sample. Single-arm studies, systematic reviews, retrospective reviews, meta-analysis, and repeat publications were also not included in the present analysis.

**Methodological quality assessment**

Followed the recommendations of the Cochrane Collaboration (Higgins et al., 2011) and the prior study (El-Khoury et al., 2013), we assessed risk of bias in domains that were most important in the study: random sequence generation (selection bias), allocation concealment (selection bias), blinding of the assessment of fall-related injury and fracture (detection bias), incomplete outcome data (attrition bias), and recall bias (over three month). We then judged each trial as a whole to ascertain whether there was low, unclear, or high risk of bias, based on whether the level of bias in each of the defined domains could have led to material biases in the risk estimates. Two authors (SFH, TTY) independently assessed the risks of bias and extracted data. Disagreements were
resolved by a third party (SFC).

**Data extraction**

To ensure the quality of the studies and conformance to the study topic, studies selected from the first screening step were read by two experienced authors, who then carried out a second step for selection and analysis based on the data extraction format. Minor discrepancies were resolved by group discussion until all members of research team agreed on the coding of characteristics.

The data extracted in the study included: study quality, sample characteristics (gender, age, history of falls), intervention characteristics (site of intervention, method, whether interveners were healthcare professionals), and types of fall-related injuries (related injury, fracture) (Table 1).

**Data synthesis and analysis**

We used comprehensive meta-analysis (version 3, Biostat, Englewood, NJ, USA) software to calculate the OR and associated 95% confidence interval (CI) for fall-related injury after fall prevention interventions. The formula for calculating effect sizes was:

$$OR = \exp (\log OR) \ (\log OR = \log (A \times D) / (B \times C))$$

For experimental group data across studies, the number of injuries was designated as A and the number of non-injuries, as B. For control group data across studies, the number of fall-related injuries/fractures was designated as C and the number of non-injuries/non-fractures, as D.

Borenstein, Hedges, Higgins, and Rothstein (2009) indicated that the random-effects model could allow the true effect to vary among studies. Because of the diverse interventions across reviewed studies, we selected the random effects model to determine the OR and associated 95% CI of the combined effect size for fall-related injuries after fall interventions; a p-value < .05 was determined as the cutoff for statistical significance. Q values and I^2 were used for heterogeneity testing.

We also did subgroup analyses to assess the influence of fall prevention programs on effect estimates: (a) participant characteristic: gender (both, female), fall history (< 20% vs. ≥ 20%); (b) intervention characteristic: site (community, facility, both), intervention (single, multiple), health professional involved (yes, no/undefined). We also did subgroup analyses to assess the influence of fall prevention programs on effect estimates and used Cochran’s Q statistic to test for subgroup interactions. Due to the heterogeneity of the data acquired, the DerSimonian and Laird (1986) random effects model was utilized. In order to measure heterogeneity, the I^2 statistic was used and scores of 25%, 50%, and 75% were considered low, moderate, and high heterogeneity, respectively.
<table>
<thead>
<tr>
<th>Study ID</th>
<th>Author/Year</th>
<th>Injury type</th>
<th>Intervention mode</th>
<th>Gender</th>
<th>Age</th>
<th>Site</th>
<th>Participants (N)</th>
<th>Intervention description</th>
</tr>
</thead>
<tbody>
<tr>
<td>01</td>
<td>Close et al. (1999)</td>
<td>Fall-related</td>
<td>Multiple</td>
<td>Both</td>
<td>78.1</td>
<td>Community</td>
<td>397</td>
<td>HEM + EDU + HA</td>
</tr>
<tr>
<td>02</td>
<td>McMurdo, Millar, and Daly (2000)</td>
<td>Fracture</td>
<td>Multiple</td>
<td>Both</td>
<td>84.3</td>
<td>Community</td>
<td>133</td>
<td>EX + RA</td>
</tr>
<tr>
<td>03</td>
<td>Hubacher and Wettstein (2001)</td>
<td>Fracture</td>
<td>Single</td>
<td>Both</td>
<td>85.6</td>
<td>Facility</td>
<td>548</td>
<td>Aids</td>
</tr>
<tr>
<td>04</td>
<td>Robertson, Devlin, Gardner, and Campbell (2001)</td>
<td>Fall-related</td>
<td>Single</td>
<td>Both</td>
<td>81.0</td>
<td>Community</td>
<td>240</td>
<td>EX</td>
</tr>
<tr>
<td>05</td>
<td>Jensen, Lundin-Olsson, Nyberg, and Gustafson (2002)</td>
<td>Fracture</td>
<td>Multiple</td>
<td>Both</td>
<td>83.5</td>
<td>Facility</td>
<td>402</td>
<td>EX + HEM + EDU + MI</td>
</tr>
<tr>
<td>06</td>
<td>Jensen, Nyberg, Gustafson, and Lundin-Olsson (2003)</td>
<td>Fracture</td>
<td>Multiple</td>
<td>Both</td>
<td>83.1</td>
<td>Facility</td>
<td>362</td>
<td>HEM + EDU + MI</td>
</tr>
<tr>
<td>07</td>
<td>Becker et al. (2003)</td>
<td>Fall-related</td>
<td>Multiple</td>
<td>Both</td>
<td>83.9</td>
<td>Facility</td>
<td>981</td>
<td>EX + HEM + EDU + RA</td>
</tr>
<tr>
<td>08</td>
<td>Barnett, Smith, Lord, Williams, and Baumann (2003)</td>
<td>Fall-related</td>
<td>Single</td>
<td>Both</td>
<td>74.9</td>
<td>Community</td>
<td>163</td>
<td>EX</td>
</tr>
<tr>
<td>09</td>
<td>Kerse, Butler, Robinson, and Todd (2004)</td>
<td>Fall-related</td>
<td>Multiple</td>
<td>Both</td>
<td>83.2</td>
<td>Facility</td>
<td>547</td>
<td>HEM + EDU + RA</td>
</tr>
<tr>
<td>10</td>
<td>Vassallo et al. (2004)</td>
<td>Fall-related</td>
<td>Multiple</td>
<td>Both</td>
<td>81.8</td>
<td>Facility</td>
<td>825</td>
<td>HEM + DM + MI + HA + RA + Aids</td>
</tr>
<tr>
<td>11</td>
<td>Dyer et al. (2004)</td>
<td>Fracture</td>
<td>Multiple</td>
<td>Both</td>
<td>87.3</td>
<td>Facility</td>
<td>196</td>
<td>EX + HEM + EDU + MI</td>
</tr>
<tr>
<td>12</td>
<td>Lord et al. (2005)</td>
<td>Fall-related</td>
<td>Multiple</td>
<td>Both</td>
<td>80.4</td>
<td>Community</td>
<td>620</td>
<td>EX + VI + Con</td>
</tr>
<tr>
<td>13</td>
<td>Davison, Bond, Dawson, Steen, and Kenny (2005)</td>
<td>Fracture</td>
<td>Multiple</td>
<td>Both</td>
<td>77.0</td>
<td>Facility</td>
<td>313</td>
<td>EX + HEM + HA + RA + Aids</td>
</tr>
<tr>
<td>14</td>
<td>Campbell et al. (2005)</td>
<td>Fall-related</td>
<td>Multiple</td>
<td>Both</td>
<td>83.6</td>
<td>Community</td>
<td>391</td>
<td>EX + HEM</td>
</tr>
<tr>
<td>15</td>
<td>Elley et al. (2008)</td>
<td>Fall-related</td>
<td>Multiple</td>
<td>Both</td>
<td>81.0</td>
<td>Community</td>
<td>312</td>
<td>EX + HEM + NS + HA + RE</td>
</tr>
<tr>
<td>16</td>
<td>Cumming et al. (2008)</td>
<td>Fall-related</td>
<td>Multiple</td>
<td>Both</td>
<td>79.0</td>
<td>Facility</td>
<td>3,999</td>
<td>EX + HEM + EDU + MI + RA + Aids</td>
</tr>
</tbody>
</table>

(continued)
Table 1

Characteristics of the Included Studies (n=33) (continued)

<table>
<thead>
<tr>
<th>Study ID</th>
<th>Author/Year</th>
<th>Injury type</th>
<th>Intervention mode</th>
<th>Gender</th>
<th>Age</th>
<th>Site</th>
<th>Participants (N)</th>
<th>Intervention description</th>
</tr>
</thead>
<tbody>
<tr>
<td>17</td>
<td>Hendriks et al. (2008)</td>
<td>Fall-related</td>
<td>Multiple</td>
<td>Both</td>
<td>74.9</td>
<td>Both</td>
<td>333</td>
<td>HEM + HA + RE</td>
</tr>
<tr>
<td>18</td>
<td>Vind et al. (2009)</td>
<td>Fall-related</td>
<td>Multiple</td>
<td>Both</td>
<td>74.4</td>
<td>Facility</td>
<td>392</td>
<td>EX + DM + MI + NS + RE</td>
</tr>
<tr>
<td>19</td>
<td>Spice et al. (2009)</td>
<td>Fracture</td>
<td>Multiple</td>
<td>Both</td>
<td>82.0</td>
<td>Community</td>
<td>505</td>
<td>HEM + RA +RE</td>
</tr>
<tr>
<td>20</td>
<td>Fitzharris, Day, Lord, Gordon, and Fildes (2010)</td>
<td>Fall-related</td>
<td>Multiple</td>
<td>Both</td>
<td>70.0</td>
<td>Community</td>
<td>1,090</td>
<td>EX + VI + HEM</td>
</tr>
<tr>
<td>21</td>
<td>Russell et al. (2010)</td>
<td>Fall-related</td>
<td>Multiple</td>
<td>Both</td>
<td>75.4</td>
<td>Community</td>
<td>698</td>
<td>HEM + RA + Con + RE + Aids</td>
</tr>
<tr>
<td>22</td>
<td>Logan et al. (2010)</td>
<td>Fracture</td>
<td>Multiple</td>
<td>Both</td>
<td>82.5</td>
<td>Community</td>
<td>204</td>
<td>EX + HEM + DM + MI + RE</td>
</tr>
<tr>
<td>23</td>
<td>Haines et al. (2011)</td>
<td>Fracture</td>
<td>Single</td>
<td>Both</td>
<td>75.3</td>
<td>Facility</td>
<td>1,206</td>
<td>EDU</td>
</tr>
<tr>
<td>24</td>
<td>Pekkarinen, Löyttyniemi, and Välimäki (2013)</td>
<td>Fracture</td>
<td>Multiple</td>
<td>Women only</td>
<td>65.3</td>
<td>Community</td>
<td>2,178</td>
<td>EX + NS + RA</td>
</tr>
<tr>
<td>25</td>
<td>Kim, Yoshida, and Suzuki (2014)</td>
<td>Fracture</td>
<td>Single</td>
<td>Women only</td>
<td>78.7</td>
<td>Community</td>
<td>196</td>
<td>EX</td>
</tr>
<tr>
<td>26</td>
<td>Hill, Etherton-Beer, and Haines (2013)</td>
<td>Fracture</td>
<td>Single</td>
<td>Both</td>
<td>78.2</td>
<td>Facility</td>
<td>50</td>
<td>EDU</td>
</tr>
<tr>
<td>27</td>
<td>Palvanen et al. (2014)</td>
<td>Fall-related</td>
<td>Multiple</td>
<td>Both</td>
<td>77.6</td>
<td>Community</td>
<td>1,314</td>
<td>EX + VI + HEM + DM + MI + NS + HA + RE + Aids</td>
</tr>
<tr>
<td>28</td>
<td>Patil et al. (2015)</td>
<td>Fracture</td>
<td>Multiple</td>
<td>Women only</td>
<td>74.2</td>
<td>Community</td>
<td>409</td>
<td>EX + NS</td>
</tr>
<tr>
<td>29</td>
<td>Karinkanta, Kannus, Uusi-Rasi, Heinonen, and Sievänen (2015)</td>
<td>Fall-related</td>
<td>Single</td>
<td>Women only</td>
<td>73.6</td>
<td>Community</td>
<td>145</td>
<td>EX + NS</td>
</tr>
<tr>
<td>30</td>
<td>El-Khoury et al. (2015)</td>
<td>Fall-related</td>
<td>Single</td>
<td>Women only</td>
<td>79.7</td>
<td>Community</td>
<td>706</td>
<td>EX</td>
</tr>
<tr>
<td>31</td>
<td>Barker et al. (2016)</td>
<td>Fall-related</td>
<td>Multiple</td>
<td>Both</td>
<td>67.5</td>
<td>Facility</td>
<td>46,245</td>
<td>HEM + Aids</td>
</tr>
<tr>
<td>32</td>
<td>Sanders et al. (2010)</td>
<td>Fracture</td>
<td>Single</td>
<td>Women only</td>
<td>76.1</td>
<td>Community</td>
<td>2,258</td>
<td>NS</td>
</tr>
<tr>
<td>33</td>
<td>Siegrist et al. (2016)</td>
<td>Fall-related</td>
<td>Multiple</td>
<td>Both</td>
<td>78.0</td>
<td>Community</td>
<td>378</td>
<td>EX + EDU + RA</td>
</tr>
</tbody>
</table>

Note. Intervention description: Exercise (EX); Visual Improvement (VI); Hazard Environmental Modification (HEM); Disease Management (DM); Education (EDU); Drug Modification (MI); Nutritional Supplements (NS); Health Assessment (HA); Fall Risk Assessment (RA); Consultation (Con); Referral (RE); Assistive Devices (Aids).
**Results**

Database searches identified 4,203 studies, and after reading the title and abstract, 3,934 studies were excluded for repeated publication, lack of statistical data on injury, and participants below 65 years. In total, 269 studies met the eligibility criteria. Further exclusion was carried out to exclude papers with no quantitative data (n=177), systematic reviews or meta-analysis (n=8), lack of control group or non-comparative study (n=27), insufficient data were reported to calculate OR (n=21), and studies with the same author and samples (n=3). A total of 33 papers were included in the meta-analysis (Figure 1).

*Figure 1. Flow Diagram of the Study Selection Process*
Characteristics of included studies and injurious falls

Thirty-three studies were included in the effect size analysis, with 68,736 participants from 11 countries. Sample sizes in individual studies ranged from 50 to 46,245 participants. Characteristics of the included studies are presented in Table 1.

In addition, the types of fall-related injuries were diverse. In reviewed studies, 14 (42.42%) reported fall-related injuries and fractures caused by falls, while 19 studies (57.58%) only described the patients who experienced fall-related injuries.

Based on the suggestion of Coe (2002), the normal distribution of effect sizes for meta-analysis was an issue that needed to be addressed. We found that the value of kurtosis of 33 effect sizes was 3.724. A value of kurtosis within the range -2 to +2 is considered acceptable for normal univariate distribution (George & Malley, 2010). After deleting the effect size of two studies (No. 9 and No. 27), which were the outliers on the both sides of the scattered plot, the value of kurtosis of 31 effect sizes decreased to 0.464 that indicated that the normal distribution was acceptable. Based on this rationale, we would like to present the meta-analyses consisting of 33 and 31 studies, respectively.

Methodological quality

The assessments of risk of bias yielded of the reviewed studies indicated excellent quality. As shown in Figure 2, all trials of reviewed studies (33/33) were at low risk of bias for sequence generation, 100% (33/33) at low allocation concealment, 93.94% (31/33) at low detection bias, 90.91% (30/33) at low attrition bias, and 96.97% (32/33) at low recall bias, respectively.

![Methodological Quality Graph](image-url)

*Figure 2. Methodological Quality Graph: Review of Authors’ Judgments About Each Methodological Quality Item Presented as Percentages Across All Included Studies.*
Effect of fall prevention programs on fall-related injury

Regarding fall-related injuries, 33 effect sizes were included in the analysis, with a combined effect size of $OR=0.86$ (95% CI: 0.75-0.97, $Z=-2.42$, $p=.016$) (Figure 3), indicating that fall prevention programs had a significant effect in decreasing fall-related injuries. Heterogeneity testing found a $Q$ value of 88.44 ($p < .001$), indicating that diversity in these 33 effect sizes were greater than that attributable to sampling error and were not homogeneous, with medium to large heterogeneity ($I^2 = 63.817$).

Figure 3. Pooled $OR$, 95% CI, Z-values, and $p$-values of Each Study Presented by Forest Plot from the Meta-Analysis of Interventions on a Number of Fall-Related Injuries

After the exclusion of outliers, 31 effect sizes were included for sensitivity analysis, with an overall effect size of $OR=0.90$ (95% CI: 0.82-0.98, $Z=-2.41$, $p=.016$), indicating that fall prevention programs had a significant effect in preventing fall-related injuries. Heterogeneity testing found a $Q$ value of 88.44 ($p < .001$), indicating that diversity in these 31 effect sizes were greater than that attributable to sampling error and were not homogeneous, with medium to large heterogeneity ($I^2 = 63.817$).
value of 40.39 ($p = .098$), indicating that these 31 effect sizes were not heterogeneous and were of low heterogeneity ($I^2 = 25.72$).

In the analysis of effect size of fall prevention programs on preventing fractures, 14 studies were included in the analysis, with a combined effect size of $OR = 0.92$ (95% CI: 0.80-1.06, $Z = -1.14$, $p = .254$) (Figure 4), showing that fall prevention programs had no significant effect in preventing fractures. The heterogeneity testing indicates these 14 effect sizes were homogenous.

After excluding the two outliers, 12 studies were included in the analysis, with an effect size of $OR = 0.80$ (95% CI: 0.63-1.03, $Z = -1.77$, $p = .077$), showing that fall prevention programs had a borderline-significant effects on preventing fractures. Heterogeneity testing found a $Q$ value of 21.86, ($p = .058$), with low to medium heterogeneity ($I^2 = 40.54$).

In the analysis of the results of various characteristics and fall-related injuries, 31 studies were included. The differences in effect sizes of the moderators in fall-related injuries were: sample including both male and female participants ($OR = 0.90$, 95% CI: 0.84-0.97, $p = .006$), participants’ falling history $\geq 20\%$ ($OR = 0.88$, 95% CI: 0.79-0.97, $p = .008$), intervention site was in the community ($OR = 0.90$, 95% CI: 0.84-1.00, $p = .010$), multiple interventions ($OR = 0.90$, 95% CI: 0.83-0.96, $p = .003$), and interventions involved healthcare professionals ($OR = 0.91$, 95% CI: 0.84-0.99, $p = .022$) (Table 2).

![Figure 4. Pooled OR, 95% CI, Z-values, and $p$-values of Each Study Presented by Forest Plot from the Meta-Analysis of Interventions on Number of Fractures](image-url)
### Table 2

**Summary of Subgroup Analyses for Meta-Analysis**

<table>
<thead>
<tr>
<th></th>
<th>Deleted outliers</th>
<th></th>
<th></th>
<th>Not deleted outliers</th>
<th></th>
</tr>
</thead>
<tbody>
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<td></td>
<td>Effect size and 95% CI</td>
<td>Heterogeneity</td>
<td></td>
<td>Effect size and 95% CI</td>
<td>Heterogeneity</td>
</tr>
<tr>
<td></td>
<td>Number studies</td>
<td>Point estimate</td>
<td>Lower estimate</td>
<td>Upper estimate</td>
<td>p-value</td>
</tr>
<tr>
<td><strong>Participant characteristic</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Both</td>
<td>25</td>
<td>0.90</td>
<td>0.84</td>
<td>0.97</td>
<td>.006</td>
</tr>
<tr>
<td>Female</td>
<td>6</td>
<td>0.94</td>
<td>0.80</td>
<td>1.09</td>
<td>.394</td>
</tr>
<tr>
<td>Falling history</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt;20%</td>
<td>2</td>
<td>0.90</td>
<td>0.78</td>
<td>1.04</td>
<td>.138</td>
</tr>
<tr>
<td>≥20%</td>
<td>22</td>
<td>0.88</td>
<td>0.79</td>
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<tr>
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Discussion

In the present review, we pooled the effects of 33 RCTs to examine the overall effect of fall prevention interventions on fall-related injuries. The quality of reviewed studies was at low risk in several types of bias based on the recommendations of the Cochrane Collaboration. We found that a fall prevention intervention had a positive effect on fall-related injuries, but its effect on fracture injuries was borderline-significant. In addition, subgroup analyses indicate that the moderators include gender, participants’ falling history, intervention site, multiple interventions, and interventions involving healthcare professionals.

Here we presented a meta-analysis that showed that fall prevention programs for older participants had a significant positive effect in preventing fall-related injuries, although the effect size was small. Gates, Fisher, Cooke, Carter, and Lamb (2008) carried out a meta-analysis on the effects of multiple evaluations and interventions on older adults from the community and emergency care in preventing fall-related injuries; the results showed that fall prevention interventions had no significant effects in preventing related injuries, in contrast to the results of the study. It could be due to the limited number of studies included in the Gate’s meta-analysis (Gates et al., 2008) (n=8). The meta-analysis of El-Khoury et al. (2013) found that exercise interventions could reduce all types of fall-related injuries in community-dwelling older adults, which is similar to that of ours. There are multiple predisposing factors for fractures resulting from falls. El-Khoury et al. (2013) who also found that exercise interventions could significantly decrease the rate of fractures in community-dwelling older adults (pooled effect of 0.39, 95% CI: 0.23-0.66, I²=0, six studies). Oliver et al. (2007) found that multiple interventions in hospitals and care homes did not show any significant preventive effects on falls resulting in fractures (RR=0.59, 95% CI: 0.22-1.58, 13 studies, and RR=0.91, 95% CI: 0.54-1.53, 8 studies). The combined effect size was also small, which could be due to the small number of studies. Our findings were similar to that of the study conducted by Oliver et al. (2007), even if we included the 14 studies to be reviewed.

Stevens and Sogolow (2005) found that elderly patients who had non-fatal fall-related injuries and who were sent for medical treatment consisted mostly of women. Fractures were the most commonly observed injuries. Women had a higher incidence of two or more prior fractures or limb injuries as compared to men. Therefore, they recommended that fall intervention programs should consider gender differences. Heesch, Byles, and Brown (2008) investigated the association between falls and physical activity in 8,188 community-dwelling elderly women. Their results showed that
people with higher physical activity had a lower possibility of incurring a fracture within 6 years ($OR=0.53$, 95% CI: 0.34-0.83, $p=.01$). Clemson et al. (2004) carried out a fall prevention program applying multiple interventions on community-dwelling elderly who had experienced a fall in the past year. Results showed that both genders had a 31% reduction in falls ($RR=0.69$, 95% CI: 0.50-0.96, $p=.025$), with a 68% reduction in falls in men only ($RR=0.32$, 95% CI: 0.17-0.59, $p=.003$). In addition, the meta-analysis ($n=4$) performed by Robertson, Campbell, Gardner, and Devlin (2002) found that exercise interventions could reduce 35% of falls and fall-related injuries, with similar effects between both genders. The gender effects in the reduction of fall-related injuries of fall prevention programs still were not consistent across previous studies. Findings from our meta-analysis indicate that the subgroup with both genders presented a significant effect on fall-related injuries, but this was not the case with the subgroup of only female participants, and this revealed the differences on reduction effects on fall-related injuries between both genders. The inconsistency in the findings of studies suggests that the protective effects of intervention of fall prevention on injury will be different depending on the gender and the type of intervention program.

Chang et al. (2004) pointed out that implementing a multiple fall prevention program would be most feasible by targeting selected participants, such as those with a history of falls. The meta-analysis found study participants with a history of falls ≥ 20% who had undergone fall prevention programs showed an improvement in fall-related injuries. Hence, older participants who have experienced falls should be encouraged to participate in fall prevention programs.

The intervention sites were classified into community and institution. Fall preventive interventions conducted in the community showed a significant effect in reducing related injuries, as compared to those conducted in institutions. However, the comparison of fall incidence in the community versus institutions for older adults may be biased because of different health status, age, and physical functions. Further studies are needed to more deeply assess the effectiveness of preventive effects on fall-related injuries among institutionalized older adults.

Goodwin et al. (2014) conducted a meta-analysis ($n=17$), showing that multiple interventions could help reduce the number of individuals who fell ($RR=0.85$, 95% CI: 0.80-0.91) and the incidence of falls ($RR=0.80$, 95% CI: 0.72-0.89). Campbell and Robertson (2007) also pointed out that multiple interventions were effective in reducing falls, regardless of whether the intervention was targeted at individuals or communities. Our findings also suggest that multiple interventions had a significant effect in reducing fall-related injuries and may result from the reduced risk of falling.

Although multifactorial fall risk assessment and intervention seems a plausible and attractive strategy for preventing falls and fall-related injuries in older people it is not supported by strong
Current evidence suggests that it may reduce the number of fallers by only a modest amount. Evidence of its effects on other outcomes such as the rate of falls and injuries is insufficient. Higher intensity interventions that provide treatments to address risk factors rather than information and referral may be more effective (Gates et al., 2008). In addition, the prior studies revealed that length of exercise intervention is associated with fall prevention (El-Khoury et al., 2013; Sherrington, Tiedemann, Fairhall, Close, & Lord, 2011; Sherrington et al., 2008). It may be the truth that the effective strategies and higher intensity interventions are necessary to be included in the fall prevention. However, in 22 analyzed studies with multifactorial interventions, duration time of each intervention in each study is not described clearly, such as referral, health assessment, fall risk assessment, hazard environmental modification. Therefore, analysis related to duration time of each intervention in each study can be discussed in the future research. Tinetti (2003) suggested that provision of effective interventions on fall prevention programs needed to consider the involvement of experienced healthcare professionals. A meta-analysis by Gillespie et al. (2012) found that when occupational therapists participated in the community fall prevention and home improvement programs for high-risk elderly, and when family physicians participated in medication adjustment intervention programs, there is a significant decrease in falls in the elderly. In the present meta-analysis, the presence of healthcare professionals as program implementers also contributed to the reduction on fall-related injuries. The results support that healthcare professionals play roles of guards in fall prevention works. Through referral, health assessment, fall risk assessment, hazard environmental modification, they can protect older adults from fallings and injuries. Further studies may explore the role of the healthcare professionals on the preventive effects of fall-related injuries.

**Strengths and limitations**

This meta-analysis has several limitations. First, because the power of our meta-analysis was large enough to make the findings robust, we did not include articles published before 1996. Second, if a trial did not report the desired statistic values for calculating OR and 95% CI, it was not included in the meta-analyses.

The strengths of our meta-analysis are that it included a high number of studies in the analyses, and that it found significant moderators on the preventive effect in fall-related injuries. Fall prevention programs are a promising intervention to reduce the incidence of falling and accompanying fall-related injuries. Given the paucity of RCT on fall-related fractures, we suggest that further studies should report the outcome of fractures after participants’ falls to examine possible protective effects of fall prevention interventions. Therefore, we suggest that future fall
prevention trials should regularly report the outcomes of fall-related injuries and fractures separately. Because fractures, especially hip fractures, can incapacitate older adults, they can lead to disability and death (Marks, 2011). The potential effects of fall prevention programs on injurious fractures need to be emphasized. If the researchers and practitioners regularly deliver the fall prevention programs to older adults, caregiver’s burden and medical care expenses caused by falls will be promising to decrease.

Conclusions

The study conducted a meta-analysis to analyze the effect sizes of fall prevention programs in preventing fall-related injuries. Results showed that fall prevention programs had a significant effect in preventing fall-related injuries with a small effect size, but a borderline statistically significant effect in preventing fractures. Subgroup analyses found subgroups with both genders combined, participants’ history of falls ≥ 20%, community as intervention site, multiple interventions, and studies involved healthcare professionals as interveners showed significant effect sizes.

The present study included more studies to show that fall prevention programs for the older adults had a significant effect in preventing fall-related injuries, providing a reference for policy makers and practitioners regarding fall prevention programs for the older adults.

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預防計畫對於老人跌倒相關傷害之成效：統合分析

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摘要

本研究目的為評估預防計畫對老人跌倒相關傷害之成效，從Cochrane Library、Medline、PubMed、PsycARTICLES、PsycINFO、ERIC、AgeLine、CINAHL、Psychology、Behavioral Sciences Collection databases等，蒐集所有相關的臨床隨機試驗研究，文獻年代範圍從1996年至2016年間，並應用探索性統合分析，計算老人跌倒預防計畫之效果量。共計33篇期刊論文納入分析（68,736人），探索性統合分析結果顯示，跌倒預防計畫因跌倒所造成的傷害具顯著效果（OR = 0.86, 95% CI: 0.75-0.97），但是對於骨折的預防效果則介於邊緣性顯著差異（OR = 0.80, 95% CI: 0.63-1.03）。此外，跌倒預防計畫若不分男女、介入內容包含健康管理專家、當參與者超過20%具跌倒經驗、社區為介入場域、包含多元介入等，本研究發現預防計畫對於預防跌倒相關傷害具有顯著的效果。因此，未來規劃跌倒預防計畫時，政策制定者及臨床工作者應考量不同特性的老人，並提出合適的介入計畫。

關鍵詞：老人、統合分析、跌倒預防、意外跌倒、傷害

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