A CRITICAL REVIEW OF THE EFFECTIVENESS OF ENVIRONMENTAL ASSESSMENT AND MODIFICATION IN THE PREVENTION OF FALLS AMONGST COMMUNITY DWELLING OLDER PEOPLE

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ABSTRACT

The potential of environmental assessment and modification to reduce falls has recently received attention within the gerontology literature. Research investigating the clinical effectiveness of this intervention in falls prevention reports conflicting results. Discrepancies are due to variation in the risk profile of study participants and the health care background of the person providing the environmental intervention or the intensity of the intervention provided. The purpose of this paper is to compare and contrast two systematic reviews, which include meta-analyses, of environmental interventions for falls prevention in community dwelling older people, using the Critical Appraisal Skills Programme tool for systematic reviews.
Both reviews found that: environmental assessment and modification was effective in falls prevention; intervention was effective with high but not low risk participants; and that high intensity environmental assessment was effective, whereas low intensity intervention was not. Environmental interventions which were delivered by Occupational Therapists were deemed high intensity, probably because their underpinning theoretical frameworks focus on the impact of the environment on function. We discuss possible reasons why Occupational Therapist led environmental assessment and modification is clinically effective in falls prevention, for people at high risk of falls, whereas non Occupational Therapist led intervention is not.

INTRODUCTION

Environmental hazards are implicated as a major contributor to falls amongst older people and are one of the most frequently cited causes of falls in the literature. One review described 'accident/environment related' factors as responsible for a mean of 31% (range 1-53%) of all falls (n=3,628) across twelve studies (Rubenstein, 2006). Similarly, a retrospective study by Talbot et al (2005) observed 'accident/environment' factors to be the second most commonly perceived cause of falls by older people, specifically identifying wet and uneven surfaces, objects on floors, external forces and icy surfaces as key contributors. Consequently, environmental assessment and modification has featured heavily in multi-factorial intervention strategies designed to prevent falls.

It is important to point out that the term 'environmental assessment and modification' possesses a specific meaning in the context of community fall prevention interventions. It has previously been described as a process whereby:

"Therapists assess the home environment and make recommendations for safety: provide advice and are actively involved in modifications; have an educating role in increasing awareness of falls and causes of falls; ensure self-monitoring of some hazards; and ensure safe transfer techniques" (Clemson, 1997, p21).

The focus on environmental assessment and modification rests on the premise that falls among older people can be reduced by modification of the environment. This is achieved through two key mechanisms, namely 1) by minimising known falls hazards and 2) by changing how a person interacts with their surroundings. Environmental interventions have, therefore, traditionally fallen within the domain of Occupational Therapy practice due to a natural alignment between Occupational Therapy frameworks (Law et al., 1996) and the aims of clinical environmental assessments. Occupational Therapy led environmental assessment normally takes the form of comprehensive assessment of the older person, the activity in which they are engaged and the environment, with interventions consisting of person, activity and environment focused strategies.

Seven randomised controlled trials (RCTs) have examined the clinical effectiveness of environmental assessment and modification in isolation from other interventions, although results have been equivocal. Three studies demonstrated a statistically significant reduction in falls (Campbell et al., 2005; Nikolaus & Bach, 2003; Pighills, Torgerson, Sheldon, Drummond, & Bland, 2011). One showed a borderline result (Relative Risk 0.81 95% CI: 0.66 to 1.00) (Cumming et al., 1999). The remaining three trials were unable to demonstrate a statistically significant effect on falls (Day et al., 2002; Lin, Wolf, Hwang, Gong, & Chen, 2007; Stevens, Holman, D'Arcy, Bennett, & de Klerk, 2001). Two additional studies investigated environmental assessment and modification, but are not discussed in this introduction. Pardessus et al (2002) compared an intervention group who received environmental assessment plus medical review with usual care controls, thus the effect of the environmental intervention cannot be isolated from that of the medical review. Lannin et al (2007) carried out a faesibility study with 10 participants, hence, the sample was too small to provide meaningful results.

Discrepancies in research findings may be attributable to the falls risk profile of participants, the health care background of the person providing the intervention and the type of environmental intervention provided. In the above studies, 'high risk' praticipants were aged 65+ and possessed one or more of the following risk factors: history of one or more falls in the previous year; recent hospital admission; a chronic condition; or, visual impairment. 'Low risk' participants were: aged 65+; recruited from electoral roles; and, did not appear to have additional risk factors. The three studies which showed a significant effect on falls were carried out with participants who were deemed at high falls risk, through having a history of falls in the preceding year or a current hospital admission with associated functional decline. In addition, the environmental intervention was delivered by Occupational Therapists and was of high intensity. High intensity intervention comprises of a comprehensive, validated functional assessment of participants in their home environment with follow-up as indicated (Clemson, Mackenzie, Ballinger, Close, & Cumming, 2008), as opposed to low intensity intervention comprising of an environmental screen via a checklist with no functional observation undertaken (Campbell et al., 2005; Nikolaus & Bach, 2003; Pighills et al., 2011). Occupational Therapist led environmental assessment and modification in trials always met the high intensity intervention criteria. In the study that showed a borderline result (Cumming et al., 1999), participants were at low risk of falls, the intervention was delivered by

Occupational Therapists and was of high intensity; however, a pre-specified subgroup analysis revealed that the intervention was effective with the high risk participants (Relative Risk 0.64 95% CI 0.50 to 0.83). Two of the three studies that showed no effect on falls were carried out in low risk populations, the intervention was provided by health care staff other than Occupational Therapists (nurses and trained assessors respectively) and was of low intensity (Day et al., 2002; Stevens et al., 2001). The third study involved a high risk population and evaluated an environmental assessment (delivered by public health workers) of low intensity (Lin et al., 2007). Thus, in summary, trials providing Occupational Therapist led, high intensity interventions were clinically effective in high (but not low) risk populations. Trials providing intervention delivered by health care practitioners other than Occupational Therapists, of low intensity, were not clinically effective in either high or low risk populations. This suggests that environmental interventions should be of high intensity, provided by Occupational Therapists and targeted toward high risk populations.

These findings raise two questions about high risk populations: whether non-Occupational Therapist led, high intensity interventions are effective; and whether Occupational Therapist led, low intensity interventions are effective. The effect of the clinical background of the person providing high intensity environmental interventions to high risk participants was specifically explored by Pighills et al (2011). High risk participants were randomised to Occupational Therapist or trained assessor led, high intensity, environmental assessment and modification or to usual care control, in a three armed trial. There was a statistically significant reduction in falls in the Occupational Therapist led group (Rate Ratio 0.54, 95% CI 0.36 to 0.83, P=0.005), but not in the trained assessor group (Rate Ratio 0.78 CI 0.51-1.21 P=0.34), compared to controls. This suggests that, in high risk populations, non-Occupational Therapist led, high intensity environmental interventions are not clinically effective, which mirrors Lin et al's (2007) results. Low intensity Occupational Therapist led interventions, in high risk populations, have not been evaluated because Occupational Therapist led environmental assessment and modification is always high intensity due to its focus on functional independence within the context of the individual's environment (Law et al., 1996). This evidence provides the focus for the recent Occupational Therapy practice guidelines in falls prevention (College of Occupational Therapists, 2015).

Whilst the above studies have investigated the isolated effect of environmental assessment and modification on falls, until recently there have been insufficient trials to perform meta-analyses. Meta-analyses could provide robust, aggregated data on clinical effectiveness specific to: environmental assessment and modification overall; participant risk status; health care background of the person providing the intervention; and intensity of environmental intervention. Therefore, we used a systematic search process to identify reviews which met the following inclusion criteria:

- Population: Community dwelling older people
- Intervention: Environmental interventions for fall prevention
- Outcome: Accidental falls
- Design: Systematic reviews with meta-analyses

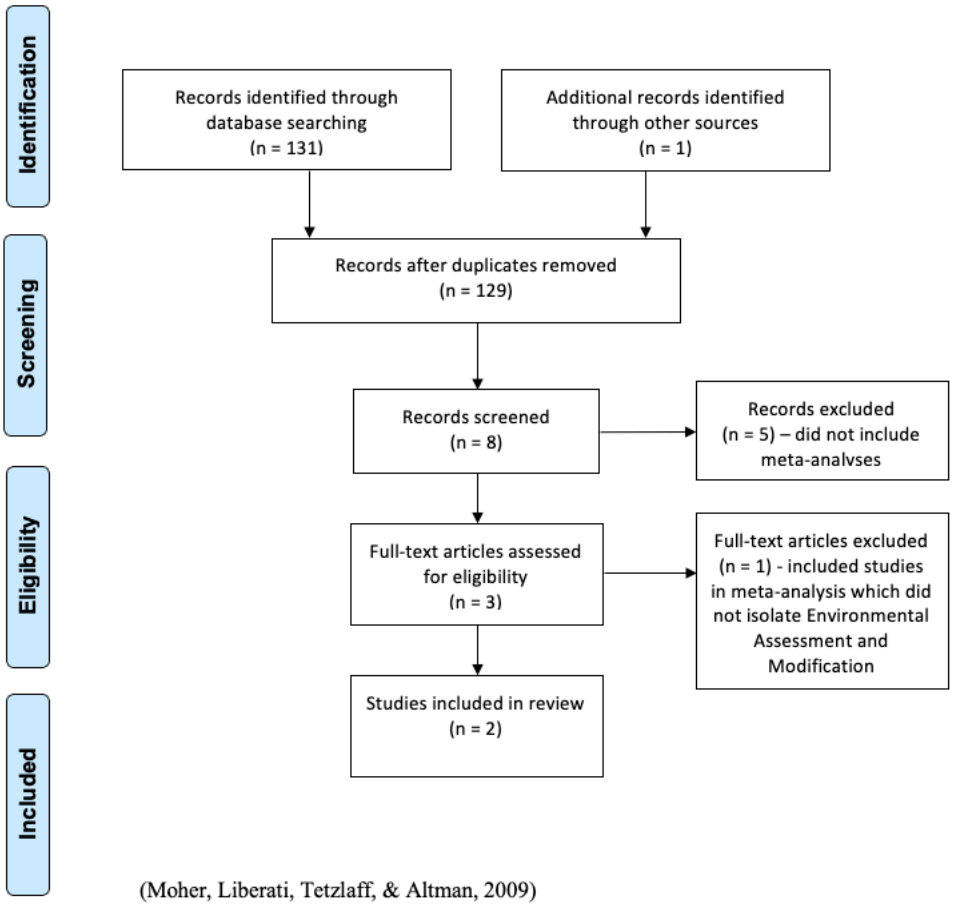
Reviews were excluded if they included trials in which the environmental intervention was a component of a multi-factorial intervention and the effect of the environmental component could not be isolated. The Cochrane, Medline, CINAHL and EMBASE electronic databases were searched from January 2000 to December 2013, using the following search terms:

- Population: Older people, frail elderly, elder*, geriatric, aged, senior

- Intervention: Home near (assessment; intervention; design; hazard; modification; safety; visit), equipment, adaptation*, assistive technology, environment near (safety; assessment; design; hazard; risk; modification), ergo, facility design and construction
- Outcome: Accidental falls
- Design: Systematic review, meta-analysis

Eight literature reviews of environmental assessment and modification were identified, three isolated the environmental interventions and included meta-analyses (see Figure 1). One review was discarded because the majority of studies included did not isolate the environmental intervention and those that did were not analysed separately (Chang et al., 2004).

FIGURE 1: Flow diagram of articles identified via literature search



(Moher, Liberati, Tetzlaff, & Altman, 2009)

The primary purpose of this paper is to compare and contrast the remaining two systematic reviews of environmental assessment and modification identified, which include meta-analyses of environmental interventions in isolation. These were published by Clemson et al (2008) (hereafter 'Clemson'), and the latest Cochrane review published by Gillespie et al (2012) ('Gillespie'). We report, compare and critique the methods and results of these two systematic reviews using sections A and B of the Critical Appraisal Skills Programme tool for systematic reviews (CASP) (Critical Appraisal Skills Programme, 2013). Section C of the CASP tool relates to the local applicability of the results which is not relevant to this paper. The following text addresses the seven questions in sections A and B of the CASP tool.

1. **Did the review address a clearly focused question?**

The aim of the Clemson review was to investigate the efficacy of environmental interventions in falls prevention. Clemson et al (2008) clarified that, to be included, a trial must investigate environmental assessment and modification as the sole intervention received, and described environmental interventions as *'... adaptations and modifications to the physical environment ... changes in individual behaviours when negotiating and interacting with the environment'* (Clemson et al., 2008, pp3). This description acknowledges the importance of the interaction between an individual and his/her environment in the causal mechanism.

The Gillespie review had a broader remit, aiming to capture trials of any intervention designed to reduce the incidence of falls in community dwelling older people. They then pooled the results of trials of comparable interventions. The group of trials relevant to this paper was 'environment/assistive technology', divided into two subgroups: 1) 'adaptations to homes and the provision of aids for personal care and protection and personal mobility' and 2) 'aids for communication, information and signalling (e.g. eyeglasses, hearing aids, personal alarm systems)' (L. Gillespie et al., 2012, p. 9). Trials were pooled for meta-analysis in the first subgroup to examine the effectiveness of 'environmental interventions alone i.e. home safety' (L. Gillespie et al., 2012, p. 9). The first subgroup has, therefore, been selected as most relevant to this paper and for comparison with the Clemson review. The categorisation of environment/assistive technology interventions within the two subgroups was transparent.

The majority of participants in the trials included by Clemson were aged 65 years or older, while Gillespie reviewed trials which included people of 60 years or more. Gillespie also included trials which recruited younger people, with specific conditions, provided that the mean age minus one standard deviation was more than 60 years. Both reviews were focused on older people living in the community, rather than in hospital or supported care.

2. **Did the reviews look for the right type of papers?**

Both reviews only included randomised controlled trials and used the comprehensive, systematic search strategy recommended by the Cochrane Collaboration (Higgins & Green, 2008). Similar bibliographic resources were interrogated by both reviews (Cochrane, MEDLINE, EMBASE, CINAHL), using comparable search terms. The terms included in both Systematic Review search strategies were based on those used in earlier versions of the Gillespie review (L. Gillespie et al., 2009; L. D. Gillespie et al., 2003).

3. **Were all the important, relevant studies included?**

Clemson's literature search identified six relevant trials, whilst Gillespie found nine in their 'Environment/Assistive Technology – home safety and aids for personal mobility' sub-grouping. Six trials were found by both searches. The three trials that were not identified by Clemson were all published after submission of their review for publication; two being published in 2007 and one in 2011 (see Table 1).

TABLE 1 Description of trials included in the Clemson and Gillespie reviews

Trial	Sample Eligibility criteria	Intervention	Intensity of intervention (met ¾) CLEMSON	Numbers	Included (quality rating*) CLEMSON	GILLESPIE
Cumming et al (1999) Australia	Aged 65+, most recruited as inpatients, also from day centre and outpatients, 39% fallen during previous year.	Intervention comprised home visit by occupational therapist, using a standard assessment, who facilitated any necessary home modifications.	HIGH	Intervention: 264 Control: 266	√ (10/10)	√ (++?+#?++)
Stevens et al (2001) Australia	Aged 70+, recruited from state electoral role.	Intervention was delivered by registered nurses, and comprised home hazards assessment, education and installation of safely devices. Control comprised one home visit with education.	NOT HIGH	Intervention: 570 Control: 1167	√ (7/10)	√ (????#+?+)
Day et al (2002) Australia	Recruited from Australian electoral roll, aged 70+.	Trained assessor delivered intervention, used structured assessment checklist of physical environment. Participants informed by letter of proposed interventions	NOT HIGH	Intervention: 543 Control: 547	√ (8/10)	√ (++?+#??+)
Pardessus et al (2002) France	Aged 65+, hospitalised for falling.	Intervention comprised home visit by occupational therapist and doctor who assessed health, home environment and functional capacity of participants. Modifications made and follow up.	HIGH	Intervention: 30 Control: 30	√ (6/10)	√ (+???##+?)
Nikolaus and Bach (2003) Germany	Recruitment from inpatient geriatric clinic, participants had previous fall and chronic conditions or deterioration.	Intervention comprised Occupational Therapy home visit, assessment of hazards, advice, facilitation of modifications and training with follow up home visit. Control was usual care.	HIGH	Intervention: 181 Control: 179	√ (10/10)	√ (+?++-+#+)
Campbell et al (2005) New Zealand	Visually impaired people aged 75+, recruited from blind register, optometry clinic, low vision clinic and ophthalmology practice.	Intervention comprised home visit by occupational therapist using modified standardised assessment. OT discussed hazards and behaviours, provision of equipment where appropriate. Control intervention consisted of social visits	HIGH	Intervention: 198 Control: 193	√ (10/10)	√ (++?+#+++)
Lannin et al (2007) Australia	Aged 65+, recruited prior to discharge from rehabilitation unit.	Intervention was delivered by an occupational therapist whilst participants were still inpatients and comprised a home visit assessment of function and environment, and education. Control was standard practice	HIGH	Intervention: 5 Control: 5	NOT RATED	√ (++?+##-?)
Lin et al (2007) Taiwan	Aged 65+, who had experience a recent fall.	Home safety and modification intervention delivered by a public health worker and comprised a list of hazards explored every two weeks for 4 months. A list of modifications was provided to participants. Modifications were completed in each participant's home. The control was education and a social visit.	NOT HIGH	Intervention: 50 Control: 50	NOT RATED	√ (????#-#+)
Pighills et al (2011) United Kingdom	Aged 70+ who had experience of a fall in the past year. Recruitment from general practitioner lists.	In this 3 arm trial, participants were randomised to receive a comprehensive environmental assessment, using a standard assessment, and installation of devices, provided by either an occupational therapist or a trained assessor (TA) or to usual care control.	HIGH	Intervention: OT group 87 TA group 73 Control: 78	NOT RATED	√ (++-+#?++)

* Quality rating: Clemson quality out of 10. Gillespie based on 8 domains (1. sequence generation; 2. allocation concealment; 3. blinding of participants and personnel; 4. blinding of outcome assessment for falls and falling; 5. blinding of outcome assessment for fractures; 6. incomplete outcome data for falls; 7. incomplete outcome data for fallers; 8. risk of bias in recall of falls). Scoring = achieved (+), not achieved (-), unclear (?) or (#) not applicable

4. Did the reviews do enough to assess the quality of the included studies?

Combinations of reviewers carried out data extraction and checking, using a pre-specified data extraction form. One or more additional reviewers resolved disagreements. Both reviews made contact with the authors of the original trials if more information was required.

Both reviews applied appropriate, rigorous quality assessment criteria (although criteria varied slightly) and quality judgement involved more than one assessor. Quality criteria were derived from pre-specified Cochrane measures of quality: the criteria used in earlier Cochrane reviews (L. Gillespie et al., 2009; L. D. Gillespie et al., 2003) and the Cochrane Handbook (Higgins & Green, 2008) with some additional questions.

The Gillespie review assessed the risk of bias in eight domains: sequence generation; allocation concealment; blinding of participants and personnel; blinding of outcome assessment for falls and falling; blinding of outcome assessment for fractures; incomplete outcome data for falls; incomplete outcome data for fallers; risk of bias in recall of falls. Studies were assigned a "+" to indicate that they fulfilled this criterion, a "–" if they did not, a "?" if it could not be ascertained, and were left blank if it was not applicable.

Clemson used eight of eleven quality criteria from an earlier Cochrane review (L. D. Gillespie et al., 2003). Blinding of participants and trial interventionists were excluded, because blinding is impossible in environmental interventions. Clemson included two additional criteria: potential for selection bias in randomisation generation, and contamination bias.

Sub-group analysis - intensity of intervention

The Clemson review included an additional step in which the intervention was rated as 'high intensity' or 'not high intensity' according to four pre-specified criteria reflecting best practice (Peterson & Clemson, 2008): a) comprehensive assessment, taking into consideration both individual and environmental characteristics; b) use of a validated assessment tool; c) consideration of the functional performance of the individual within the context of their environment; and d) provision of follow up and support. An intervention was required to fulfil a minimum of three of these four criteria to be rated as 'high intensity'.

Clemson's intensity rating required close scrutiny of the intervention provided within included trials. Depending on the quality of reporting, it can be difficult to find objective evidence to support each criterion. However, the intensity criteria do provide an additional means to differentiate between interventions in order to identify aspects which constitute best practice.

Sub-group analysis - delivery personnel
The Gillespie review additionally examined the effectiveness of environmental assessment and modification if provided by an Occupational Therapist as opposed to other personnel. This sub-group analysis was conducted as a consequence of the trial by Pighills et al (2011) which found that there were significantly less falls in the Occupational Therapist led environmental assessment group compared to controls, but not in the group where the intervention was provided by trained assessors.

Quality appraisal
The quality ratings of the six trials common to both reviews were generally in agreement, with Campbell et al (2005), Cumming et al (1999) Nikolaus and Bach (2003) given the highest quality rating by Clemson (10/10), and receiving five or more out of a possible eight '+' marks from Gillespie. The Day et al (2002) trial achieved four out of the possible eight '+' marks in Gillespie, but was rated lower by Clemson, losing points for 'comparability of groups at baseline' and 'potential bias, as hazard assessment was conducted with both intervention and control'. Of the six common trials, both Pardessus et al (2002) and Stevens et al (2001) received the lowest quality ratings, scoring only two '+' by Gillespie (although for different criteria), and scores of 6 and 7 respectively by Clemson. Both reviews were generally in agreement about the strengths (low risk of bias in recall of falls) and weaknesses (sequence generation, allocation concealment, and blinding to falls) of these two trials. Of the trials that were included in the Gillespie review only (thus not scored by Clemson), Pighills et al (2011) was rated alongside the higher quality rated studies receiving five out of a possible eight '+' marks, Lannin et al (2007) received three and Lin (2007) one. It is likely that Clemson's quality rating would have concurred with Gillespie's for these three studies.

5. If the results of the review have been combined, was it reasonable to do so?
The Clemson review pooled the results of the primary outcome measure reported (either the number of falls sustained or the number of people who fell) in one analysis. Comparisons between intervention and control were expressed as relative risks with associated confidence intervals. Gillespie was more comprehensive: separate analyses were carried out for the number of falls sustained (Rate Ratio) and the number of people who fell (Risk Ratio), where these data were available. Confidence intervals were reported for both measures.

Analysis
Clemson pooled the data from individual trials within a random effects meta-analysis, whereas Gillespie performed fixed effect meta-analysis, which is generally assumed to be more likely to produce significant results. In the Clemson review, two sub-analyses were stated a priori: first, a subgroup analysis of participants at high risk of falling at baseline; and second, a sub-analysis restricted to those trials evaluating high intensity interventions. Gillespie also reported two a priori sub-analyses, for which they used a random effects model: trials involving participants at high risk of falling; and healthcare background of the person carrying out the environmental intervention.

Tests of heterogeneity were carried out within both reviews. In the Clemson meta-analysis significant heterogeneity was found between trials and was subsequently explored through sensitivity analyses. Heterogeneity within the Gillespie meta-analysis was explored by comparison of the effects of intervention between trials recruiting only participants at high risk of falls and those not restricting recruitment to high-risk groups, and a sub-group analysis based on the clinical background of the person providing the environmental intervention.

6. What are the overall results of the reviews?

Table 1 describes the trials included in one or both of the Clemson and Gillespie Systematic Reviews. The quality appraisals from both reviews are presented along with Clemson's evaluation of the intensity of intervention.
The results from the two meta-analyses are summarized in Table 2. In the overall analysis Clemson found a 21% reduction in falls favouring the intervention (Relative Risk 0.79, 95% confidence interval 0.65 to 0.97). Gillespie also found a significant effect in favour of the environment/assistive technology interventions, for number of falls (Rate Ratio 0.81, 95% confidence interval 0.68 to 0.97) and number of people who fell (Risk Ratio 0.88, 95% confidence interval 0.80 to 0.96), based on six trials presenting fall rate ratios and seven trials presenting fall risk ratios.

TABLE 2 Comparison of the findings between the Clemson and Gillespie meta-analyses

	Clemson Rate and Risk of falls (relative risk)	Gillespie Rate of falls (rate ratio)	Gillespie Risk of falling (risk ratio)
Overall analysis			
Trials included	Cumming (1999) Stevens (2001) Day (2002) Pardessus (2002) Nikolaus (2003) Campbell (2005)	Cumming (1999) Stevens (2001) Day (2002) Nikolaus (2003) Campbell (2005) Lin (2007)	Cumming (1999) Stevens (2001) Day (2002) Pardessus (2002) Campbell (2005) Lannin (2007) Pighills (2011)
Pooled effect size (95% CI)	0.79 (0.65 to 0.97)	0.81 (0.68 to 0.97)	0.88 (0.80 to 0.96)
Test for overall effect	P=0.007	P=0.022	P=0.0028
Significance of heterogeneity	P<0.01 I^2=69%	P=0.02 I^2=64%	P=0.73 I^2=0%
High risk sub-analysis	Sub-group of trial participants with a known risk factor at baseline	Trials only including people with a history of falling or other risk factor	
Trials included	Cumming (1999) Pardessus (2002) Nikolaus (2003) Campbell (2005)	Nikolaus (2003) Campbell (2005) Lin et al (2007)	Pardessus (2002) Campbell (2005) Pighills (2011)
Pooled effect size (95% CI)	0.61 (0.47 to 0.79)	*0.62 (0.50 to 0.77)	**0.85 (0.75 to 0.97)
Test for overall effect	P<0.05	P=0.000019	P=0.017
Significance of heterogeneity	P=0.16 I^2=42%	P=0.54 I^2=0%	P=0.45 I^2=0%
Low risk sub-analysis	N/A	Trials not restricting entry to people at high risk of falling	
Trials included		Cumming (1999) Stevens (2001) Day (2002)	Cumming (1999) Stevens (2001) Day (2002) Lannin (2007)
Pooled effect size (95% CI)	N/A	*0.94 (0.84 to1.05)	**0.90 (0.80 to 1.00)
Test for overall effect	N/A	P=0.26	P=0.059
Significance of heterogeneity	N/A	P=0.44 I^2=0%	P=0.63 I^2=0%
High intensity / OT led intervention sub-analysis	Intervention high intensity if ≥3 of the 4 best practice criteria met	OT led environmental assessment and modification	
Trials included	Cumming (1999) Pardessus (2002) Nikolaus (2003)	Cumming (1999) Nikolaus (2003) Campbell (2005)	Cumming (1999) Pardessus (2002) Campbell (2005)

	Clemson Rate and Risk of falls (relative risk)	Gillespie Rate of falls (rate ratio)	Gillespie Risk of falling (risk ratio)
	Campbell (2005)	Pighills (2011)	Lannin (2007) Pighills (2011)
Pooled effect size (95% CI)	0.68 (0.50-0.91)	#0.69 (0.55-0.86)	##0.79 (0.70-0.91)
Test for overall effect	Highly effective	P=0.0013	P=0.00072
Significance of heterogeneity	Not stated	P=0.07 I^2=58%	P=0.95 I^2=0%
Low intensity /non-OT led intervention sub-analysis	Intervention low intensity if ≤2 of the 4 best practice criteria met	Environmental assessment and modification provided by a heath care worker other than an Occupational Therapist	
Trials included	Day (2002) Stevens (2001)	Stevens (2001) Day (2002) Lin (2007) Pighills (2011)	Stevens (2001) Day (2002) Pighills (2011)
Pooled effect size (95% CI)	0.96 (0.84-1.09)	#0.91 (0.75-1.11)	##0.94 (0.85-1.05)
Test for overall effect	Not effective	P=0.34	P=0.31
Significance of heterogeneity	Not stated	P=0.16 I^2=42%	P=0.83 I^2=0%

Footnote:

* Test for subgroup differences in rate of falls between high risk and low risk groups P<0.01, I^2=91%

** Test for subgroup differences in risk of falling between high risk and low risk groups P=0.57, I^2=0%

\# Test for subgroup differences in rate of falls between high intensity/OT led and low intensity/not OT led groups P=0.07, I^2=70%

\## Test for subgroup differences in risk of falling between high intensity/OT led and low intensity/not OT led groups P=0.05, I^2=74%

Subgroup analyses

Subgroup analyses were carried out by both Clemson and Gillespie to explore the impact of environmental interventions in groups at higher and lower risk of falling, rated at recruitment. Clemson found a statistically significant reduction in falls of 39% in the high-risk sub-group (Relative Risk 0.61, 95% confidence interval 0.47 to 0.79). Gillespie found that both the number of falls and the number of people who fell were significantly reduced in the higher risk subgroup (Rate Ratio 0.62, 95% confidence interval 0.50 to 0.77; Risk Ratio 0.85, 95% confidence interval 0.75 to 0.97) but not in the lower risk subgroup (Rate Ratio 0.94, 95% confidence interval 0.84 to 1.05; Risk Ratio 0.90, 95% confidence interval 0.80 to 1.00).

Clemson also carried out a sub-analysis of trials according to intensity of intervention and found that the four trials with an intervention rated as having high intensity (Campbell et al., 2005; Cumming et al., 1999; Nikolaus & Bach, 2003; Pardessus et al., 2002) were effective in reducing falls (Relative Risk 0.68, 95% confidence interval 0.50 to 0.91). These four trials were also those where the intervention was carried out by an Occupational Therapist. Conversely, those with interventions rated as low-intensity (Day et al., 2002; Stevens et al., 2001) did not significantly reduce the number of falls (Relative Risk 0.96, 95% confidence interval 0.84 to 1.09) and were carried out by healthcare workers other than occupational therapists.

In the Gillespie sub-group analysis of trials in which the environmental intervention was provided by Occupational Therapists, they found that the Occupational Therapist led trials showed a statistically significant reduction in the number of falls (Rate Ratio 0.69 95% CI 0.55 to 0.86, 1443 participants, 4 trials) and the number of people who fell (Risk Ratio 0.79, 95%CI 0.70 to 0.91, 1153 participants, 5 trials). However, there was no statistically significant difference in the pooled data from the trials that were not Occupational Therapist led: either in the number of falls (Rate Ratio 0.91, 95% CI 0.75 to 1.11, 3075 participants, 4 trials) or in the number of people who fell (Risk Ratio 0.94, 95% CI 0.85 to 1.05, 2975 participants, 3 trials).

The results of the Gillespie delivery personnel sub-analysis were similar to Clemson's intensity of intervention sub-analysis because high intensity interventions were provided by Occupational Therapists, thus, the trials included in the two sub-analyses were the same. The Gillespie sub-analysis included three additional studies which were published after the Clemson review had been submitted for publication (Lannin et al., 2007; Lin et al., 2007; Pighills et al., 2011).

7. How precise are the results?

Estimates of effect for the overall analysis in both meta-analyses are bound by 95% Confidence Intervals which have a range varying from plus or minus 8% to plus or minus 16% (see Table 2). The Confidence Interval range for the subgroup analyses is plus or minus 9% to plus or minus 20.5%. This suggests that the estimates are imprecise as the confidence intervals are relatively wide, possibly because there were few studies in the meta-analyses and the majority had relatively small sample sizes.

DISCUSSION

Environmental assessment and modification significantly reduces the number of falls that people experience and the number of people who fall. The relative risks, fall rate and risk ratios in the Clemson and Gillespie meta-analyses were similar in direction and magnitude (Relative Risk 0.79, Rate Ratio 0.81, Risk Ratio 0.88). This is unsurprising as the reviews included the same studies, with the exception of three additional studies included in the Gillespie review, which were not published in time for inclusion by Clemson.

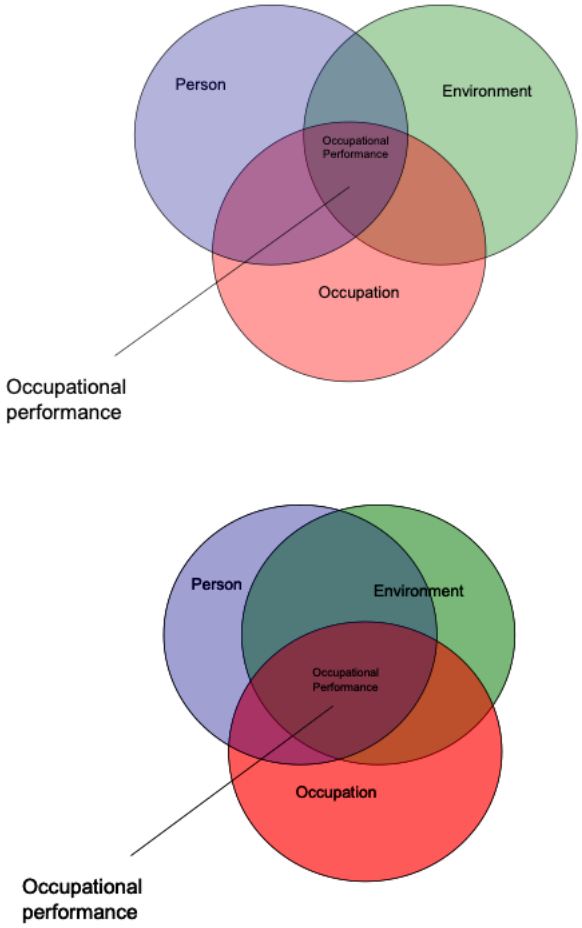
The impact of risk status and intensity of intervention / Occupational Therapist led intervention was explored by both reviews through two sub-group analyses. The rationale for choosing the high/low risk sub-group analysis was based on a large body of evidence demonstrating that falls prevention interventions are more effective in high risk populations (Robertson & Gillespie, 2013). However, the rationale behind the intensity and Occupational Therapist led intervention subgroup analyses differed for the two meta-analyses; even though the two meta-analyses appeared to be examining different sub-groups, by default they included the same studies. Gillespie carried out a sub-group analysis of Occupational Therapist led intervention because a recent study (Pighills et al., 2011) showed that Occupational Therapy led environmental intervention significantly reduced the number of falls, whereas trained assessor led intervention did not. Clemson had previously researched the components of environmental assessment (Clemson, 1997; Clemson, Donaldson, Hill, & Day, 2014) and was aware of the importance of functional assessment in environmental interventions. Clemson, therefore, carried out a sub-group analysis based on the intensity of

the environmental intervention. Of interest, the high intensity and Occupational Therapist led intervention sub-group analyses included the same studies, as did the low intensity and non-Occupational Therapist led intervention sub-group analyses, with the exception of the three additional studies included in the Gillespie review. Therefore, the sub-group analysis results were similar between the two meta-analyses, indicating that intervention with high risk participants and Occupational Therapist led / high intensity interventions were clinically effective.

When Occupational Therapists provide environmental interventions they incorporate Clemson's four quality criteria, which is why Occupational Therapist led interventions were classed as high intensity. Occupational Therapists are educated to consider the person within the context of the environment, to focus on occupational performance and, where possible, to use standardised measures. The Person, Environment, Occupation (PEO) conceptual model of Occupational Therapy practice (Law et al., 1996) assumes that people constantly interact with their environment, which provides the context for their performance in everyday activities (occupational performance). This model not only explains the interaction between the three elements of person, environment and activity, but also illustrates the potential for improved occupational performance (such as reducing the risk of a fall when completing a task).

Occupational performance is influenced by the person performing a task, their environment and the nature of the activity, and can be improved, most effectively, by interventions involving all three components (Law et al., 1996). The potential effect of high intensity environmental interventions, which additionally address the individual and the activity (occupation), on occupational performance, is reflected in Figure 2 below. If all three components improve then occupational performance is enhanced. However, if the person and occupation elements either remain unchanged or regress and the environment is manipulated in isolation, occupational performance has limited scope for improvement and may even deteriorate.

FIGURE 2 The interaction of person, environment and activity as described within the PEO model



The PEO model explains why the epidemiological literature has struggled to establish an association between environmental variables and falls. Observational studies report that the mere presence of environmental hazards is not associated with falls (Campbell, Borrie, Spears, & Jackson, 1990; Gill, Williams, & Tinetti, 2000). Falls appear to be caused by a combination of intrinsic and behavioural factors in the context of the environment, rather than simply caused by the environment per se.

Risk factors, in addition to the environment, mediate the falls risk posed in any given situation. These additional factors comprise of the falls risk status of the older person (intrinsic risk) and behaviour (behavioural risk). Behavioural risk factors include: routines; frequency of use of space; and the occupational activity in which the person is engaged (Pighills et al., 2011; Todd, Ballinger, & Whitehead, 2007). These categories mirror those of the PEO model of Occupational Therapy practice. Thus, when Occupational Therapists deliver environmental interventions to prevent falls, they address a range of risk categories and carry out functional assessment with the person in their own environment, which are components of Clemson's intensity of intervention criteria and may explain why Occupational Therapist led intervention is effective. The potential of environmental intervention using the PEO model has long been recognised within the sphere of professional practice of Occupational Therapy, with a paper from as early as 1990 highlighting that 85% of

falls occur in the home and advocating that Occupational Therapy professional practice should address education, environmental safety and risk taking behaviours (Walker & Howland, 1990). As far back as 1996 Clemson et al stated that:

"Home hazard assessment that ignores the functional status of the person living in the assessed home is meaningless" (Clemson, Cumming, & Roland, 1996, p. p100, p100).

Functional assessment within the context of an individual's environment, and the environmental demand placed upon the individual, are crucial to gauge occupational performance. The demand that environments exert on individuals (extrinsic risk) is known as "*environmental press*" and is a component of man/ environment relations (MER) theory (Lawton, Windley, & Byers, 1982). Environmental Press is related to a person's competence or functional ability (intrinsic risk) and the demands of the activity in which they are engaged (behavioural risk). An individual's behaviour, at a given level of competence (motor, sensory, perceptual and cognitive status), when presented with environmental demand, is either adaptive or maladaptive. Low competence and high environmental press may result in maladaptive behaviour, such as activity avoidance or risk taking, which could result in falls. Small changes in environmental demand, as opposed to intrinsic change, produce greater variations in behaviour in less competent individuals. This suggests that behaviour change can be achieved through environmental change (Lawton et al., 1982). However, caution must be exercised to avoid overly adapting the environment to the extent that it can no longer exert the appropriate level of environmental press to optimise function. Occupational Therapists are trained to strike this balance through activity analysis and requisite skills development to enhance function and wellbeing. Because of this frame of reference, Occupational Therapists do not provide low intensity environmental interventions; hence the lack of evidence relating to low intensity Occupational Therapist led environmental assessment and modification.

Recent research (Iwarsson, Horstmann, Carlsson, Oswald, & Wahl, 2009) supports the hypothesis that environmental interventions should address how the environment is used by older people and the demands it places upon them. This requires active participation in the assessment. Iwarsson and colleagues (2009) carried out assessments of the 'fit' between the older person and their environment, using a computer based assessment, the 'Housing Enabler'. Community dwelling older adults (n=834) were recruited to the study and followed up one year after the initial assessment to determine how many falls they had experienced during the previous twelve months. Whilst the number of objective environmental hazards was similar for older people who fell and those who did not, the number of person-environment fit problems (a variable determined within the Housing Enabler assessment) was higher for the group who had fallen. The 'person-environment fit' variable was also a significant predictor of falls, with odds ratio of 1.025 (P=0.037), whilst the number of environmental hazards was not.

Occupational Therapist led environmental assessment and modification is appropriately conceptualised as a complex intervention with multiple mechanisms of effect (Creek, 2003). There is potential for oversimplification of research findings when the results of trials are explained using a single dimension of 'intervention intensity'. However, Clemson's criteria do provide a means of describing and comparing falls prevention environmental interventions. These criteria reinforce the conditional nature of hazards within an environment which, in combination with intrinsic factors and particular activities and behaviours, combine to create risk. Clemson et al (2008) propose that, in contrast to a view of environmental hazards as

objective and static, Occupational Therapy practice recognises the agency of older people, and their capacity to problem solve with client-centred therapists, in order to reduce their likelihood of an adverse event such as a fall. Clemson's criteria could be used to distinguish different types of environmental interventions, in much the same way as the categories of exercise, proposed within the Prevention of Falls Network for Europe (ProFaNE) taxonomy (Lamb, Jorstad-Stein, Hauer, & Becker, 2005), formed the basis for the categorisation of exercise interventions within the Gillespie review.

Environmental interventions in fall prevention have increasingly been investigated whilst, concurrently, theory around mechanisms of successful environmental interventions has been developed. These represent exciting developments in the evolution of research. Fruitful areas for further research within this domain include: evaluating the clinical effectiveness of environmental interventions provided by professions more closely aligned with Occupational Therapy, such as Physiotherapy; the use of different techniques for actively engaging older people in addressing environmental concerns; and exploration of strategies in the wider environment, in addition to the home. Qualitative studies could distill the components of Occupational Therapy led environmental assessment and elicit the perspectives of older people and health care providers about what appears to reduce falls risk and why. With the publication of new studies, the need for ongoing systematic reviews and meta-analyses also remains a priority.

CONCLUSION

Occupational Therapist led environmental assessment and modification is clinically effective in reducing falls in high risk older people. This is likely to be because their intervention considers personal, environmental and activity related falls risk factors and recognises the agency of the person in moderating risk.

Key findings

- Objective assessment and modification of purely environmental fall risk hazards are unlikely to be successful
- The conceptual basis for Occupational Therapy practice in falls prevention has proven effectiveness

What the study has added

In contrast to exercise interventions, environmental assessment and modification within the context of falls prevention has been under theorised. Principles, including the acknowledgement of the service user as an active agent, explain the success of Occupational Therapy within this context.

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References:

Campbell, A. J., Borrie, M. J., Spears, G. F., & Jackson, S. L. (1990). Circumstances and consequences of falls experienced by a community population 70 Years and over during a prospective study. *Age and Ageing, 19*(2), 136-141.

Campbell, A. J., Robertson, M. C., La Grow, S. J., Kerse, N. M., Sanderson, G. F., Jacobs, R. J., . . . Hale, L. A. (2005). Randomised controlled trial of prevention of falls in people aged 75 with severe visual impairment: the VIP trial. *British Medical Journal, 10*, 1136-1143. Retrieved from http://bmj.bmjjournals.com/cgi/rapidpdf/bmj.38601.447731.55v1?maxtoshow=&HITS=10&hits=10&RESULTFORMAT=1&author1=Campbell%2C+AJ&author2=Robertson%2C+MC&title=Randomised+controlled+trial+of+prevention+of+falls&andorexacttitle=and&andorexacttitleabs=and&andorexactfulltext=and&searchid=1128333306607_3109&stored_search=&FIRSTINDEX=0&sortspec=relevance&resourcetype=1,2,3,4

Chang, J. T., Morton, S. C., Rubenstein, L. Z., Mojica, W. A., Maglione, M., Suttorp, M. J., . . . Shekelle, P. G. (2004). Interventions for the prevention of falls in older adults: systematic review and meta-analysis of randomised clinical trials. *British Medical Journal, 328*(7441), 680-683. Retrieved from www.otseeker.com https://www.ncbi.nlm.nih.gov/pmc/articles/PMC381224/pdf/bmj32800680.pdf

Clemson, L. (1997). *Home fall hazards: a guide to identifying fall hazards in the homes of elderly people and an accompaniment to the assessment tool, the Westmead Home Safety Assessment (WeHSA)*. West Brunswick Victoria: Co-ordinates Publications.

Clemson, L., Cumming, R. G., & Roland, M. (1996). Case control study of hazards in the home and risk of falls and hip fractures. *Age and Ageing, 25*(2), 97-101. Retrieved from http://ageing.oxfordjournals.org/content/25/2/97.full.pdf

Clemson, L., Donaldson, A., Hill, K., & Day, L. (2014). Implementing person-environment approaches to prevent falls: A qualitative inquiry in applying the Westmead approach to occupational therapy home visits. *Australian Occupational Therapy Journal*, n/a-n/a. doi:10.1111/1440-1630.12132

Clemson, L., Mackenzie, L., Ballinger, C., Close, J., & Cumming, R. G. (2008). Environmental interventions to prevent falls in community-dwelling older people: A meta-analysis of randomized trials. *Journal of Ageing and Health, 20*(8), 954-971. doi:10.1177/0898264308324672

College of Occupational Therapists. (2015). *Falls: the role of occupational therapy in the prevention and management of falls - practice guideline*. Retrieved from London:

Creek, J. (2003). *Occupational therapy defined as a complex intervention*. Retrieved from London:

Critical Appraisal Skills Programme. (2013). 10 questions to help you make sense of a review.

Cumming, R. G., Thomas, M., Szonyi, G., Salkeld, G., O'Neill, E., Westbury, C., & Frampton, G. (1999). Home visits by an occupational therapist for assessment and modification of environmental hazards: A randomised trial of falls prevention. *Journal of the American Geriatrics Society, 47*, 1397-1402.

Day, L., Fildes, B., Gordon, I., Fitzharris, M., Flamer, H., & Lord, S. (2002). Randomised factorial trial of falls prevention among older people living in their own homes. *British Medical Journal, 325*(7356), 128-131. Retrieved from https://www.ncbi.nlm.nih.gov/pmc/articles/PMC117228/pdf/128.pdf

Gill, T. M., Williams, C. S., & Tinetti, M. E. (2000). Environmental hazards and the risk of non syncopal falls in the homes of community-living older persons. *Medical Care, 30*(12), 1174-1183.

Gillespie, L., Robertson, M., Gillespie, W., Lamb, S., Gates, S., Cumming, R., & Rowe, B. (2009). Interventions for preventing falls in older people living in the community. *Cochrane Database of Systematic Reviews*(2), CD007146. doi:10.1002/14651858.CD007146.pub2

Gillespie, L., Robertson, M., Gillespie, W., Sherrington, C., Gates, S., Clemson, L., & Lamb, S. (2012). Interventions for preventing falls in older people living in the community. *Cochrane database of Systematic Reviews,*(9), 1-416. doi:DOI: 10.1002/14651858.CD007146.pub3.

Gillespie, L. D., Gillespie, W. J., Robertson, M., Lamb, S. E., Cumming, R. G., & Rowe, B. (2003). Interventions for preventing falls in elderly people (Cochrane Review). *The Cochrane Library*, 1-96.

Higgins, J. P., & Green, S. (Eds.). (2008). *Cochrane Handbook for Systematic Reviews of Interventions*. Chichester: John Wiley & Sons, Ltd.

Iwarsson, S., Horstmann, V., Carlsson, G., Oswald, F., & Wahl, H.-W. (2009). Person—environment fit predicts falls in older adults better than the consideration of environmental hazards only. *Clinical Rehabilitation, 23*(6), 558-567. doi:10.1177/0269215508101740

Lamb, S. E., Jorstad-Stein, E. C., Hauer, K., & Becker, C. (2005). Development of a common outcome data set for fall injury prevention trials: The Prevention of Falls Network Europe consensus. *Journal of the American Geriatrics Society, 53*(9), 1618-1622. doi:10.1111/j.1532-5415.2005.53455.x

Lannin, N. A., Clemson, L., McCluskey, A., Wei, C., Lin, C., Cameron, I. D., & Barras, S. (2007). Feasibility and results of a randomised pilot-study of pre-discharge occupational therapy home visits. *BMC Health Services Research, 7*(42), 1-8. doi:doi:10.1186/1472-6963-7-42

Law, M., Cooper, B., Strong, S., Stewart, D., Rigby, P., & Letts, L. (1996). The person-environment-occupation model: a transactive approach to occupational performance. *Canadian Journal of Occupational Therapy, 63*, 9-22.

Lawton, M. P., Windley, P. G., & Byers, T. D. (Eds.). (1982). *Ageing and the environment: theoretical approaches*. New York: springer.

Lin, M.-R., Wolf, S. L., Hwang, H.-F., Gong, S.-Y., & Chen, C.-Y. (2007). A Randomized, Controlled Trial of Fall Prevention Programs and Quality of Life in Older Fallers. *Journal of the American Geriatrics Society, 55*(4), 499-506. Retrieved from http://www.blackwell-synergy.com/doi/abs/10.1111/j.1532-5415.2007.01146.x

Nikolaus, T., & Bach, M. (2003). Preventing falls in community dwelling frail older people using a home intervention team: Results from the randomised falls-HIT trial. *Journal of the American Geriatrics Society, 51*, 300-305. doi:10.1046/j.1532-5415.2003.51102.x

Pardessus, V., Puisieux, F., Di Pompeo, C., Gaudefroy, C., Thevenon, A., & Dewailly, P. (2002). Benefits of home visits for falls and autonomy in the elderly: a randomized trial study. *American Journal of Physical Medicine & Rehabilitation, 81*(4), 247-252. Retrieved from http://www.amjphysmedrehab.com/pt/re/ajpmr/issuelist.htm

Peterson, E. W., & Clemson, L. (2008). Understanding the role of occupational therapy in fall prevention for community-dwelling older adults. *OT Practice, 13*(3), CE-1-CE-8, 2p. Retrieved from

https://search.ebscohost.com/login.aspx?direct=true&AuthType=ip&db=rzh&AN=20009872543&site=ehost-live

Pighills, A. C., Torgerson, D. J., Sheldon, T. A., Drummond, A. E., & Bland, J. M. (2011). Environmental assessment and modification to prevent falls in older people. *Journal of the American Geriatrics Society, 59*(1), 26-33. doi:10.1111/j.1532-5415.2010.03221.x

Robertson, M., & Gillespie, L. D. (2013). Fall prevention in community-dwelling older adults. *JAMA, 309*(13), 1406-1407. doi:10.1001/jama.2013.3130

Rubenstein, L. Z. (2006). Falls in older people: epidemiology, risk factors and strategies for prevention. *Age and Ageing, 35*(Supplement 2), ii37-ii41. doi:10.1093/ageing/afl084

Stevens, M., Holman, C., D'Arcy, J., Bennett, N., & de Klerk, N. (2001). Preventing falls in older people: outcome evaluation of a randomised controlled trial. *Journal of the American Geriatrics Society, 49*, 1448-1455.

Talbot, L., Musiol, R., Witham, E., & Metter, E. J. (2005). Falls in young, middle-aged and older community dwelling adults: perceived cause, environmental factors and injury. *BMC Public Health, 5*(1), 1-9. doi:10.1186/1471-2458-5-86

Todd, C., Ballinger, C., & Whitehead, S. (2007). *A global report on falls prevention: Reviews of socio-demographic factors related to falls and environmental interventions to prevent falls amongst older people living in the community*. Retrieved from Geneva: http://www.who.int/ageing/projects/3.Environmental%20and%20socioeconomic%20risk%20factors%20on%20falls.pdf

Walker, J. E., & Howland, J. (1990). Falls and fear of falling among elderly persons living in the community: occupational therapy interventions. *The American Journal of Occupational Therapy, 45*(2), 119-122.