Developing a multi-systemic fall prevention model, incorporating the physical environment, the care process and technology: a systematic review

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Abstract

Aims. This paper reports a review that assessed the effectiveness and characteristics of fall prevention interventions implemented in hospitals. A multi-systemic fall prevention model that establishes a practical framework was developed from the evidence.

Background. Falls occur through complex interactions between patient-related and environmental risk factors, suggesting a need for multifaceted fall prevention approaches that address both factors.

Data sources. We searched Medline, CINAHL, PsycInfo and the Web of Science databases for references published between January 1990 and June 2009 and scrutinized secondary references from acquired papers.

Review methods. Due to the heterogeneity of interventions and populations, we conducted a quantitative systematic review without a meta-analysis and used a narrative summary to report findings.

Results. From the review, three distinct characteristics of fall prevention interventions emerged: (1) the physical environment, (2) the care process and culture and (3) technology. While clinically significant evidence shows the efficacy of environment-related interventions in reducing falls and fall-related injuries, the literature identified few hospitals that had introduced environment-related interventions in their multifaceted fall intervention strategies.

Conclusion. Using the multi-systemic fall prevention model, hospitals should promote a practical strategy that benefits from the collective effects of the physical environment, the care process and culture and technology to prevent falls and fall-related injuries. By doing so, they can more effectively address the various risk factors for falling and therefore, prevent falls. Studies that test the proposed model need to be conducted to establish the efficacy of the model in practice.

Keywords: injuries, nursing, patient falls, patient safety, physical environment, prevention, risk factors, systematic review
Introduction

Falls are the most common adverse events reported in hospitals across the United States (US), England, Wales, Australia and elsewhere (Morgan et al. 1985, Gaebler 1993, Williams et al. 2007, Healey et al. 2008). The rate of falls ranges from 2.3 to 7 falls per 1000 patient days (Lane 1999, Halfon et al. 2001, Hitchco et al. 2004). Up to 33% of reported hospital inpatients fall in hospital (Morgan et al. 1985), with 4–6% resulting in serious injuries (Morse et al. 1985, Ash et al. 1998, Hitchco et al. 2004) that may lead to impaired rehabilitation and co-morbidity (Bates et al. 1995) and even death (Hitcho et al. 2004, Oliver et al. 2004). Falls are also associated with increases in hospital stays and healthcare costs and higher rates of both discharges to long-term institutional care and litigation against hospitals (Oliver et al. 2004). As of 1 October 2008, the US government social insurance programme Medicare no longer reimburses for costs associated with patient injuries resulting from falls and trauma that occur during hospital stays (Centers for Medicare & Medicaid Services 2008). Thus, patient falls are not only harmful but also costly to both patients and hospitals. In this paper, we review the literature exploring interventions implemented in all relevant domains of hospitals and their efficacy on falls and fall-related injuries and their underlying mechanisms. We then propose a multi-systemic model of fall prevention that allows healthcare professionals to plan, to implement and to evaluate fall prevention design strategies that mitigate fall risks and injuries in their healthcare infrastructure and recapitalization investment.

Intrinsic and extrinsic fall risk factors

Research shows that hospitals can reduce the incidence and severity of falls by identifying risk factors and introducing appropriate interventions that reduce them (Brandis 1999, Barry et al. 2001, Haines et al. 2004, Fonda et al. 2006, Williams et al. 2007). Risk factors include both intrinsic and extrinsic factors, and a complex interaction of such factors can result in a fall (The Joint Commission 2005a). Intrinsic factors involve patient-related characteristics such as age and disease and include previous falls, reduced vision, unsteady gait, musculoskeletal system deficits, mental status deficits, acute illness and enduring illnesses such as neurological diseases (Stolze et al. 2004, The Joint Commission 2005a). Extrinsic factors mostly relate to the physical environment of hospitals, including medication (especially sedative/hypnotics), lack of support equipment near bathtubs and toilets, inappropriate design of furnishings, the condition of floors, poor illumination, inappropriate footwear, improper use of devices (e.g. bedrails) and inadequate assistive devices (e.g. lifting device, walkers, and wheelchairs) (The Joint Commission 2005a, Tzeng & Yin 2008). For example, root-cause analyses of data on falls for all patients admitted over a 3-year period in geriatric acute care units in Australia identified factors such as ward equipment (e.g. beds) and furniture (e.g. chairs), lighting, and floor surfaces as key contributing factors (Fonda et al. 2006). In a report to the Joint Commission outlining the latest sentinel event tracking efforts from 1995 to 2004 (The Joint Commission 2005b), the physical environment was also cited as one of the root causes of 144 fatal falls in 24-hour care settings.

Safe environments for America’s heroes: the approach of the US Military Health System

The Military Health System (MHS) finds itself in a unique position to transform its worldwide healthcare infrastructure into a safe, supportive, and healing environment through the largest projected construction programme in its history. A number of forces have converged to create unprecedented opportunities for change. The 2005 Base Realignment and Closure (BRAC) law facilitated greater integration and more effective coordination of health services across the Air Force, Army, and Navy (Defense Base Closure and Realignment Commission 2005), coinciding with the restructuring and relocation of many military units across the globe. In the current Department of Defense (DoD) programme budget development, with the support of the department’s leadership and the United States Congress, the MHS will for the first time achieve a consistent level of investment supporting a 31-year recapitalization and renewal rate of military health facilities on a consistent and predictable basis. Over the next 5 years, the military medical construction programme anticipates investments of approximately $11B encompassing over 100 capital projects across the globe. Given the magnitude of investment, the MHS leadership has committed to creating a physical environment that promotes healing that will lead to improved outcomes, safety and efficiency (Ossmann et al. 2008). One key issue driving future designs is the prevention of patient falls and injuries. For example, the patient rooms of a new military hospital at Fort Belvoir have bathrooms on the headwall with a supportive railing directly leading from the bed to the bathroom. Recently, the MHS has also instituted a major programme to examine the causes of falls and ways to mitigate them. According to reports of sentinel events by Military Treatment Facilities (MTFs) to the Patient Safety Analysis Center (PSC), patient falls are still among the leading causes of injury. Thus, they pose an important threat to patient safety.
The review

Aims

The purpose of this review is threefold: (1) to evaluate the effectiveness of interventions implemented throughout all relevant hospital domains on primary outcomes of interest (i.e. a reduction or no reduction in inpatient falls and fall-related injuries); (2) to determine the characteristics of interventions that can later facilitate the identification of the underlying mechanisms of interventions attributable to the primary outcomes in hospital settings; (3) to develop a hypothesis-generating multi-systemic model that establishes a practical framework in which hospital executives and nursing administrators can operate to develop a balanced fall prevention strategy that acts upon the physical environment, the care process and the culture and technology.

Design

For the current review, we followed the guidelines of an internationally recognized organization (Centre for Reviews and Dissemination 2009). The guidelines outline the methods and steps necessary to conduct a systematic review in healthcare research and aims to avoid the risk of introducing bias. Due to the heterogeneity of interventions and populations, we conducted a quantitative systematic review without a meta-analysis and used a narrative summary technique to report findings.

Search methods

We searched Medline, CINAHL, PsycINFO and the Web of Science for references in peer-reviewed journals published between January 1990 and June 2009 that pertained to interventions targeting adult hospital inpatient populations with the aim of reducing falls and fall-related injuries. The search applied combinations of the search terms ‘falls’, ‘injury’, ‘intervention’, ‘prevention’, ‘hospital design’, ‘physical environment’ and ‘ergonomics’ (Table 1). In addition, we searched for secondary references from acquired papers, review articles and authoritative texts. One primary reviewer conducted the study selection, data extraction and quality assessment under the supervision of another reviewer. Issues arising from the processes were resolved through discussion between the reviewers.

In a two-phase search strategy, we initially searched for fall prevention interventions with the primary outcomes – a reduction or no reduction in falls and fall-related injuries – through changes in all relevant domains in hospital settings and then added 25 studies during this process; then once noting the dearth of research pertaining to environment-related interventions in hospital settings, we also sought studies that evaluated the effect of environment-related interventions or factors on not only the primary outcomes but also associated intermediate outcomes such as a reduction in postural sway to enhance understanding of the underlying mechanisms of environmental factors that may produce the primary outcomes and added nine studies during this process.

The two-phase search strategy involved two different inclusion criteria. In the first phase, it included studies that (1) tested an intervention aimed at reducing falls and fall-related injuries in adult hospital inpatient populations and (2) reported the primary outcomes – a reduction or no reduction in falls and fall-related injuries. In the second phase, it included studies that (1) tested an environment-related intervention or factor whose purpose was to reduce falls and fall-related injuries in three adult populations (i.e. hospital inpatients, long-term care inpatients and the elders) and (2) reported either the primary outcomes or any associated intermediate outcomes. Included throughout the phases were the following study designs: randomized controlled, quasi-randomized controlled, controlled before-and-after, historically controlled and cohort studies. Excluded throughout the phases were studies that neither reported the original research nor gave sufficient details about the research design or the components of the interventions, studies with duplicate hits and studies published in languages other than English.

Search outcome

The two-phase search strategy produced 6723 studies (See supporting information Table S1 in the online version of the article in Wiley online Library). After applying the inclusion and exclusion criteria to the titles and the abstracts from the first screening, we excluded 6680 studies. We retrieved the full texts of the remaining 53 studies. The second screening of the full texts led to the removal of 19 additional studies. Thus, a total of 6697 studies were excluded and 34 studies included after the first and second screening processes (Figure 1).

Quality appraisal

The methodological quality of the studies was assessed by a checklist containing 27 questions developed by Downs and Black (1998) and designed for randomized and non-randomized studies. To weight the appraisal criteria differently, we did not rate them numerically. The first author evaluated the 34 studies under the supervision of another author. The fulfilment of the quality criteria
<table>
<thead>
<tr>
<th>Reference</th>
<th>CI</th>
<th>Settings</th>
<th>Study design</th>
<th>Mean age (years/sample size)</th>
<th>Components of interventions</th>
<th>Findings</th>
<th>Number of falls</th>
<th>Fall rate</th>
<th>Falls with serious injuries (%)</th>
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</thead>
<tbody>
<tr>
<td>Cumming et al. (2008)</td>
<td>MH</td>
<td>24 elderly care wards in 12 hospitals in Sydney, Australia</td>
<td>Cluster randomized controlled</td>
<td>79/3999 patients</td>
<td>EN, CP&amp;C, T-related: (1) A structured fall risk assessment, (2) targeted interventions for high risk patients, and (3) minor environmental modifications</td>
<td>No sizable reductions in either falls or fall-related injuries in the intervention group</td>
<td>194 falls (IG)/ 190 falls (CG)</td>
<td>9.26 falls (IG)/ 9.20 falls (CG) per 1000 patient-days</td>
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<tr>
<td>Krauss et al. (2008)</td>
<td>MH</td>
<td>Four general medicine floors (two intervention and two control floors) in a 1300-bed urban tertiary-care academic hospital, USA</td>
<td>Quasi-experimental with historical and contemporaneous controlled</td>
<td>65.5 ± 18.1 (IG), 65.5 ± 17.5 (CG)/57 patients (IG), 78 patients (CG)</td>
<td>EN, CP&amp;C, T-related: (1) A structured fall risk assessment, (2) targeted interventions for high-risk patients, and (3) minor environmental modifications</td>
<td>A sizable reduction in falls (23% fewer falls) in the intervention group (a 9-month period)</td>
<td>57 falls (IG)/78 falls (CG)</td>
<td>5.09 falls (IG)/ 6.64 falls (CG) per 1000 patient-days</td>
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<td>Capan &amp; Lynch (2007)</td>
<td>MH</td>
<td>Medical/neurology units in a 357-bed acute care hospital, USA</td>
<td>Before and after</td>
<td>NA (patients of all ages)</td>
<td>CP&amp;C, T-related: (1) A structured fall risk assessment, (2) targeted interventions for all patients at a high risk of falling (a total score of 30 or greater), (3) additional interventions, targeting individual-specific risk factors, and (4) re-administration of fall risk assessment every 12 hours</td>
<td>Sizable reductions in falls and fall-related injuries during the intervention: Total fall rate dropped from 0.45 per 100 patient-days to 0.32 per 100 patient-days. Severity of fall-related injuries also declined. Falls with minor and severe injuries decreased by 52% and 86%, respectively</td>
<td>NA</td>
<td>4.5 (BI)/3.2 (AI)</td>
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## Table 1 (Continued)

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<tr>
<td>Williams et al. (2007)</td>
<td>MH</td>
<td>Three medical wards (comprising 72 beds) and a 17-bed geriatric evaluation unit in an acute tertiary teaching hospital, Australia</td>
<td>Before and after (6-month period)</td>
<td>79/1357 patients</td>
<td>EN-, CP&amp;C-, T-related: (1) A structured fall risk assessment and (2) differentiated targeted interventions for each level of fall-risk patients</td>
<td>A statistically significant reduction in falls from 0.95% to 0.8% (95% CI: for the difference −0.14 to −0.16, P &lt; 0.001) but no substantial changes in the severity of falls during the intervention</td>
<td>NA</td>
<td>0.95 (BI)/0.8 (AI)</td>
<td>NA</td>
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<tr>
<td>Von Renteln-Kruse &amp; Krause (2007)</td>
<td>MH</td>
<td>Geriatric wards in an academic teaching hospital, Germany</td>
<td>Historically controlled before and after</td>
<td>81.9 ± 7.9 (BI), 82.2 ± 7.7 (AI)/4272 patients (BI), 2981 patients (AI)</td>
<td>CP&amp;C-, T-related: (1) A structured fall risk assessment on admission (STRATIFY), reassessment after a fall and (2) targeted interventions for high-risk patients</td>
<td>A statistically significant reduction in the rate of falls from 10.0 to 8.2 (IRR: 0.82, 95% CI: 0.73–0.92, P &lt; 0.001) but no significant or sizable reductions in fall-related injuries from 26.9% to 27.6% during the intervention</td>
<td>893 falls</td>
<td>10.0 (BI)/8.2 (AI)</td>
<td>NA</td>
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<td>Schwendimann et al. (2006)</td>
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<td>Three departments in a 300-bed hospital, Switzerland</td>
<td>Before and after</td>
<td>67.3 ± 19.3/34,972 patients</td>
<td>EN-, CP&amp;C-, and T-related: (1) fall risk assessment, (2) targeted interventions for patients at high risk of falling, and (3) additional interventions, generally applied to all patients</td>
<td>A slight decrease in the rate of falls to 7.87 falls per 1000 patient days (P = 0.086) during the intervention</td>
<td>7.87 falls per 1000 patient days (AI)</td>
<td>NA</td>
<td>NA</td>
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<td>Fonda et al. (2006)</td>
<td>MH</td>
<td>Acute care units for the older people, Australia</td>
<td>Historically controlled before and after (2-year period)</td>
<td>80/1905 patients (Bl), 2260 patients (Al-one year later), 2056 patients (Al-two years later)</td>
<td>EN-, CP&amp;C-, and T-related: (1) A structured fall risk assessment, (2) targeted interventions for patients at high risk of falling, and (3) additional interventions, generally applied to all patients</td>
<td>Statistically significant reductions in both falls (19% fewer falls) (P = 0.001) and serious fall-related injuries (77% fewer falls resulted in injury) (P = 0.0004) in the intervention group (over a 2-year period)</td>
<td>NA</td>
<td>12.5 (Bl)/10.1 (Al) per 1000 patient-days</td>
<td>0.73 (Bl)/0.17 (Al)</td>
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<tr>
<td>Haines et al. (2004)</td>
<td>MH</td>
<td>Three sub-acute wards in a Metropolitan Hospital specializing in rehabilitation and care of elderly patients, Australia</td>
<td>Randomized controlled</td>
<td>80/626 patients</td>
<td>CP&amp;C- and T-related: (1) A structured fall risk assessment, weekly medical assessments, (2) targeted interventions for patients at high risk of falling, and (3) additional individual-specific interventions</td>
<td>A statistically significant reduction in falls (30% fewer falls) (Peto log rank test P = 0.045) and a sizable reduction in fall-related injuries (28% fewer falls resulted in injuries) in the intervention group</td>
<td>105 falls for 310 patients (IG)/149 falls for 316 patients (CG)</td>
<td>NA</td>
<td>22 (IG)/21.5 (CG)</td>
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<td>Vassallo et al. (2004)</td>
<td>MH</td>
<td>Three geriatric wards, United Kingdom</td>
<td>Quasi-experimental (open cluster randomized controlled)</td>
<td>NA/825 patients</td>
<td>EN-, CP&amp;C-, T-related: (1) A structured fall risk assessment, (2) targeted interventions for patients at high risk of falling, and (3) additional individual-specific interventions</td>
<td>A sizable reduction in falls. The result was not definitive because of the differences in patients’ average length of stay between the intervention and control groups</td>
<td>72 falls for 5855 OBDs (IG)/170 falls for 14,791 OBDs (CG)</td>
<td>NA</td>
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<td>Healey et al. (2004)</td>
<td>MH</td>
<td>Elderly care wards in a district general hospital, England</td>
<td>Paired cluster randomized controlled (6-month period)</td>
<td>80/1861 patients (CG), 1525 patients (IG)</td>
<td>EN-, CP&amp;C-related: (1) Interventions were only applied to patients at high risk and (2) patient-specific interventions</td>
<td>A statistically significant reduction in falls (RR: 1:12, 95% CI: 0:55–0.90, P = 0.006) but no significant reductions in the incidence of fall-related injuries on intervention wards</td>
<td>240 falls (BI)/180 falls (AI) for 6 months</td>
<td>14.37</td>
<td>2.69–3.07</td>
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<td>Barry et al. (2001)</td>
<td>MH</td>
<td>A rehabilitation unit, Ireland</td>
<td>Historically controlled before and after (2-year period)</td>
<td>81/156 patients (BI), 172 patients (AI)</td>
<td>EN-, CP&amp;C-, T-related: (1) A structured fall risk assessment, additional risk assessment of remediable visual problems, mobility assistance and replacement of unsuitable footwear, provision of special footwear, and medication review and modification, (2) staff education, staff questionnaires about remediable environmental hazards, (3) environmental audits and modifications, and (4) hip protectors</td>
<td>A sizable reduction in falls: 21% fewer falls in Year 1 and 49.3% fewer in Year 2; a sizable reduction in the incidence of fracture: 20.5% of falls (pre-intervention) to 2.8% in Year 1 and no fractures in Year 2, a sizable reduction in soft tissue injuries in Year 2 but not in Year 1: a drop in Injuries from 38.5% (pre-intervention) to 36.1% (Year 1) and 15.4% (Year 2)</td>
<td>71 falls (BI)/56 falls (AI) for the first year/36 falls (AI) for the second year</td>
<td>NA</td>
<td>14.7 (BI)/8.1 (AI) – first year/2.7 (AI) – second year</td>
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<td>Savage &amp; Matheis-Kraft</td>
<td>MH</td>
<td>Geriatric psychiatric wards, Canada</td>
<td>Historically controlled before and after (4-month period)</td>
<td>77.5</td>
<td>CP&amp;C related: (1) A structured fall risk assessment tool, an incident report form, and analysis and (2) patient specific interventions</td>
<td>A statistically significant reduction in falls after the intervention ($P &lt; 0.01$)</td>
<td>11 falls (BI)/1 fall (AI) for 4 months</td>
<td>NA</td>
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<td>(2001)</td>
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<tr>
<td>Brandis</td>
<td>MH</td>
<td>A 500-bed acute general hospital, Australia</td>
<td>Before and after (2-year period)</td>
<td>NA</td>
<td>EN-, CP&amp;C-, and T-related: (1) Minor modifications of bathroom details, (2) interventions for patients at high risk, and (3) staff education</td>
<td>A sizable reduction in falls (17.3% fewer falls) but no significant reductions in fall-related injuries but a sizable reduction in the number of patients sustaining injuries from falls [70% of fallers (BI) to 55.5% (AI)]</td>
<td>270 falls by 201 inpatients (BI)/258 falls by 190 inpatients (AI)</td>
<td>1.74–1.61</td>
<td>70 (BI)/55.49 (AI)</td>
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<td>(1999)</td>
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<tr>
<td>Mitchell &amp; Jones</td>
<td>MH</td>
<td>An acute/sub-acute medical ward, Australia</td>
<td>Historically controlled before and after (1-year period)</td>
<td>76</td>
<td>CP&amp;C related: (1) A specific fall assessment tool, (2) targeted interventions for high-risk patients, and (3) staff and patient education and ongoing audits and feedback</td>
<td>A sizeable reduction in falls during the intervention</td>
<td>42 falls (BI)/21 falls (AI) for 6 months</td>
<td>4.4–7.8</td>
<td>NA</td>
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<td>(1996)</td>
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<tr>
<td>Donald et al.</td>
<td>SH</td>
<td>An elder care rehabilitation ward in a community hospital, UK</td>
<td>Randomized 2 × 2 controlled</td>
<td>NS/54 consecutive patients</td>
<td>EN-related carpeted flooring/CP&amp;C-related additional exercise</td>
<td>Fewer falls on vinyl floors than on carpeted floors (relative risk: 8.3, 95% CI: 0.95–73, ( P = 0.05 )) Fewer falls in the intervention group receiving additional exercise than in the control group receiving conventional physiotherapy (relative risk: 0.21, 95% CI: 0.04–1.2, ( P = 0.12 )).</td>
<td>1 fall on vinyl flooring vs. 10 falls on carpet flooring/4 falls (IG-additional exercise)/7 falls (CG)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Hanger et al.</td>
<td>SH</td>
<td>Five elderly care hospital wards from a hospital, New Zealand</td>
<td>Prospective before and after</td>
<td>NS/792 falls out of 1968 admissions during a year</td>
<td>EN-related bedrail reduction</td>
<td>A statistically significant reduction in serious injuries in the intervention group (( P = 0.008 )) No statistically significant differences between the fall rates before and after the intervention</td>
<td>NA</td>
<td>164 (BI)/ 191 (AI) falls per 10,000 bed days</td>
<td>33 falls (BI)/18 falls w/serious injuries</td>
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<tr>
<td>Haumschild et al.</td>
<td>SH</td>
<td>A large urban rehabilitation center, USA</td>
<td>Retrospective before-and-after</td>
<td>79.6 (BI), 78.5 (AI)/200 patients (BI), 200 patients (AI)</td>
<td>CP&amp;C-related medication reviews and modifications</td>
<td>A statistically significant reduction in the number of falls (( P = 0.05 ))</td>
<td>30 falls (BI)/16 falls (AI) for 1 year each</td>
<td>NA</td>
<td>NA</td>
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<td>Mayo et al. (1994)</td>
<td>SH</td>
<td>A rehabilitation hospital, Canada</td>
<td>Stratified, randomized, balanced controlled</td>
<td>70.9 (12.6) (IG), 72.9 (11.8) (CG)/65 patients (IG), 69 (CG)</td>
<td>CP&amp;C-related identification bracelets</td>
<td>No statistical differences between the intervention and the control groups (no beneficial effects of an identification bracelet in reducing falls)</td>
<td>27 first falls (IG)/21 first falls (CG)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Bischoff et al. (2003)</td>
<td>SH</td>
<td>Long-stay geriatric care units in a geriatric university hospital, Switzerland</td>
<td>Double-blind randomized</td>
<td>85.3 (range: 63–99)/122 elder females</td>
<td>CP&amp;C-related vitamin D and calcium supplementation vs. calcium-only supplementation</td>
<td>A statistically significant reduction in the number of falls ($P &lt; 0.01$) and statistically significant improvement in musculoskeletal functions ($P = 0.0094$) in the intervention group (the Cal+D)</td>
<td>25 falls (14 persons) (IG)/55 falls (18 persons) (CG)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Haines et al. (2007)</td>
<td>SH</td>
<td>A metropolitan subacute/aged rehabilitation hospital, Australia</td>
<td>Randomized controlled, subgroup analysis</td>
<td>NS/173 patients</td>
<td>CP&amp;C-related additional exercise</td>
<td>A statistically significant reduction in the number of falls in the intervention group ($P = 0.007$)</td>
<td>8.2 falls/1000 participant-days (IG)/16.0 falls/1000 participant-days (CG)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Haines et al. (2006)</td>
<td>SH</td>
<td>A metropolitan subacute/aged rehabilitation hospital, Australia</td>
<td>Randomized controlled, subgroup analysis</td>
<td>NS/226 patients</td>
<td>CP&amp;C-related patient education</td>
<td>A statistically significant reduction in the number of falls in the intervention group ($P = 0.007$)</td>
<td>8.2 falls/1000 participant-days (IG)/16.0 falls/1000 participant-days (CG)</td>
<td>NA</td>
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Table 1 (Continued)

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<tr>
<th>Reference</th>
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<th>Mean age (years)/sample size</th>
<th>Components of interventions</th>
<th>Findings</th>
<th>Number of falls</th>
<th>Fall rate</th>
<th>Falls with serious injuries (%)</th>
</tr>
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<tbody>
<tr>
<td>Donoghue et al. (2005)</td>
<td>SH</td>
<td>An acute care unit, Australia</td>
<td>Before-and-after</td>
<td>NS/NS</td>
<td>CP&amp;C-related volunteer programme</td>
<td>A statistically significant reduction (44%) in the fall rate per 1000 bed days during the intervention (Fisher's exact chi-square, ( P &lt; 0.000; \ OR: 0.56, 95% \ CI: 0.45–0.68 )) No falls occurred when volunteers were present</td>
<td>15.6 per 1000 bed days (median: 14.5, ( SD \pm 6.5, ) range: 5.2–29.3) (BI)/8.8 per 1000 bed days (median 9.8, ( SD \pm 3.0, ) range: 1.1–13.2) (AI)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Giles et al. (2006)</td>
<td>SH</td>
<td>Medical wards in two hospitals, Australia</td>
<td>Before-and-after</td>
<td>NS/NS</td>
<td>CP&amp;C-related volunteer programme</td>
<td>No falls when volunteers were present but no significant reductions in the fall rate during the intervention</td>
<td>70 falls in 4828 OBDs (BI)/82 falls in 5300 OBDs (AI)</td>
<td>14.5 falls per 1000 OBDs (BI)/15.5 falls per 1000 OBDs (AI)</td>
<td>NA</td>
</tr>
<tr>
<td>Tideiksaar et al. (1993)</td>
<td>SH</td>
<td>A geriatric evaluation unit at a teaching hospital, USA</td>
<td>Case-controlled</td>
<td>84 (range: 67–97)/70 patients</td>
<td>T-related bed alarm</td>
<td>No statistical differences between the intervention and the control groups</td>
<td>1 fall (IG)/4 falls (CG)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Diduszyn et al. (2008)</td>
<td>SH</td>
<td>One neurology and three telemetry floors at a 500-bed acute care university hospital, USA</td>
<td>Before-and-after</td>
<td>NS/NS</td>
<td>T-related bed alarm</td>
<td>A sizable reduction (18%) in the number of falls during the 4-month intervention period</td>
<td>78 falls (BI – the same period 1 year earlier)/64 falls (AI)</td>
<td>NA</td>
<td>NA</td>
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### Table 1 (Continued)

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<th>Fall rate</th>
<th>Falls with serious injuries (%)</th>
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<tbody>
<tr>
<td>Vassallo <em>et al.</em> (2000)</td>
<td>EN</td>
<td>Three medical wards of a district general hospital, UK</td>
<td>Prospective cohort</td>
<td>64-51 (ward A), 66-48 (ward B), 64-02 (ward C)/1609 patients (ward A 678, ward B 439, ward C 492)</td>
<td><em>EN-related</em> nuclear layout wards (wards B and C) vs. a longitudinal layout ward (ward A)</td>
<td>The longitudinal layout ward (Ward A) had the most falls (31 vs. 18/14; ( P = 0.01 )), fall positive days (29 vs. 15/10; ( P = 0.002 )), and fallers (27 vs. 13/12; ( P = 0.001 ); OR: 2.54, 95% CI: 1.41-4.57). A ward layout is an important independent risk factor for falls (( P = 0.01 )) when controlling for age, sex, and diagnostic variation between the wards. When the hospital changed its coronary intensive care units from two-bed rooms to acuity-adaptable single-bed rooms with decentralized nurse stations, patient transfers decreased by 90%, falls declined by 67%, and medication errors declined by 70%</td>
<td>18 falls (ward A)/14 falls (ward B), 31 falls (ward C)</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Hendrich <em>et al.</em> (2004)</td>
<td>EN</td>
<td>An acute care hospital, USA</td>
<td>Before-and-after</td>
<td>NS/NS</td>
<td><em>EN-related</em> acuity-adaptable rooms with decentralized nurses’ stations</td>
<td>When the hospital changed its coronary intensive care units from two-bed rooms to acuity-adaptable single-bed rooms with decentralized nurse stations, patient transfers decreased by 90%, falls declined by 67%, and medication errors declined by 70%</td>
<td>2 falls per 1000 patient days (AI)</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>Reference</td>
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<td>Settings</td>
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<td>Redfern et al. (1997)</td>
<td>EN</td>
<td>A laboratory</td>
<td>Experimental</td>
<td>23.8/8 young participants 76/8 older participants</td>
<td>*EN-related floor compliance (softness) *</td>
<td>Floor compliance (softness) increased the amount of sway in older participants (F = 3.83, P &lt; 0.001). Floor compliance influences standing postural stability in older people, particularly in destabilizing visual environments</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>Dickinson et al. (2001)</td>
<td>EN</td>
<td>A laboratory</td>
<td>Experimental</td>
<td>73.25 (range: 60–88; SD ± 748/25 older adults)</td>
<td>*EN-related floor compliance (softness) *</td>
<td>The carpet increased postural sway among healthy, community-dwelling older adults (P &lt; 0.05), compared to the firm surface with no carpet and pad applied</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>Dickinson et al. (2002)</td>
<td>EN</td>
<td>A laboratory</td>
<td>Experimental</td>
<td>72.84 (SD ± 5.35/45 older adults)</td>
<td>*EN-related floor compliance (softness) *</td>
<td>No important differences between the commercial-grade carpet and the firm surface with no carpet and pad applied</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>Laing et al. (2006)</td>
<td>EN</td>
<td>A laboratory</td>
<td>Experimental</td>
<td>24 ± 3 (SD)/15 female participants</td>
<td>*EN-related floor compliance (softness) *</td>
<td>Impact forces decreased with increasing floor softness (P &lt; 0.001)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Reference</td>
<td>CI</td>
<td>Settings</td>
<td>Study design</td>
<td>Mean age (years)/sample size</td>
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<td>Sran &amp; Robinovitch (2008)</td>
<td>EN</td>
<td>A laboratory</td>
<td>Experimental</td>
<td>25 ± 5 (SD)/11 young male participants</td>
<td><em>EN-related floor compliance</em> (softness)</td>
<td>Impact forces decreased with increasing floor softness (<em>P</em> &lt; 0.001)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Healey (1994)</td>
<td>EN</td>
<td>An elderly care unit, UK</td>
<td>Retrospective cohort</td>
<td>NS/NS</td>
<td><em>EN-related carpeted flooring vs. vinyl flooring</em></td>
<td>Out of a group of patients falling on carpet, only 17% sustained injuries. In the group of patients who fell on vinyl, 46% sustained injuries (<em>P</em> &lt; 0.01)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Simpson et al. (2004)</td>
<td>EN</td>
<td>34 residential care homes, UK</td>
<td>Prospective cohort</td>
<td>NS/NS</td>
<td><em>EN-related carpeted flooring with wooden sub-flooring</em></td>
<td>Carpeted floors with wooden sub-flooring were associated with the lowest number of fractures per 100 falls. The risk of fracture resulting from a fall was significantly lower compared to all other floor types (odd ratio: 1.78, 95% CI: 1.33–3.35).</td>
<td>266 falls (wood-uncarpeted)/492 falls (concrete-uncarpeted)/2,812 (wood-carpeted)/3,071 (concrete-carpeted)</td>
<td>NA</td>
<td></td>
</tr>
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</table>

CI, characteristic of intervention; MH, multifaceted interventions in a hospital setting; SH, single interventions in a hospital setting; EN, environmental research (non-interventional); EN-related, environment-related interventions; P&C-related, care process & culture-related interventions; T-related, technology-related interventions; BI, before intervention; AI, after intervention; IG, intervention group; CG, control group; OBDs, occupied bed days; NS, not specified.
differed across the studies (see supporting information Table S2 in the online version of the article in Wiley online Library – Quality appraisal of studies). However, the authors did not exclude any of the studies because the heterogeneity of their designs, apart from their quality of research, played an important role in determining if the quality criteria were accounted for.

Data abstraction and synthesis

From the final 34 studies, the following data were extracted and inserted into a table including the setting, the study design and population (mean age and sample size), the components of the interventions, the findings and the outcomes of interest (Table 1).

Results

Multifaceted fall prevention interventions

Fourteen studies that tested multifaceted fall prevention interventions in hospital settings were included in the review (See supporting information Table S3 in the online version of the article in Wiley online Library). Twelve out of the 14 multifaceted fall interventions resulted in either an important or sizable reduction in falls or fall-related injuries. Two studies report no sizable or important reduction in falls: a quasi-experimental study in three geriatric wards in the United Kingdom (UK) (Vassallo et al. 2004) and a cluster randomized trial in 24 older people care wards with relatively short lengths of stay in 12 hospitals in Australia (Cumming et al. 2008). However, because of the multifaceted nature of the interventions, it is difficult to isolate the effect of an individual intervention to determine which component of the interventions contributed to associated outcomes (a reduction or no reduction in falls). Thus, an in-depth analysis of the characteristics and the mechanisms of individual fall prevention interventions of the 14 multifaceted fall interventions was conducted. The analysis identified not only a wide range of currently available individual interventions but also three distinct characteristics of interventions: (1) the physical environment, (2) the care process and culture and (3) technology-related interventions. Table S3 presents currently available individual interventions that are part of...
multifaceted interventions in hospitals, categorized into the three distinct characteristics of interventions (See supporting information Table S3 in the online version of the article in Wiley online Library).

Single environment-related interventions

Environmental assessment and modification
While identifying seven studies that implemented an environmental assessment and modification intervention as part of their multi-faced fall prevention intervention strategies (See supporting information Table S3 in the online version of the article in Wiley online Library), the review identified no studies in healthcare settings that tested the efficacy of environmental modification interventions as a single intervention.

Carpeted flooring
The review identified only one environmental factor, flooring, tested as a single intervention in a hospital setting (Donald et al. 2000). A 9-month randomized 2 x 2 controlled trial of 54 consecutive patients at elderly care rehabilitation wards in the UK found that fewer falls occurred on vinyl floors (one) than on carpeted floors (ten) \((P = 0.05)\). Although counter-intuitive, the study indicates that vinyl floors decrease the risk of falling. However, as the study was limited by a small sample size \((n = 54)\) with limited sensitivity to the measures (only 15 falls), further research is needed.

Bedrail reduction
One bedrail reduction programme with appropriate staff education effectively reduced the number of serious injuries in elderly care hospital wards in New Zealand (Hanger et al. 1999). While finding an insignificant increase in the number of falls, this 1-year prospective before-and-after study involving a total of 1968 patient admissions found a significant decline in the number of serious fall-related injuries after the bedrail reduction policy and education programme were introduced \((33\text{ serious injuries vs. 18 serious injuries, } P = 0.008)\) (Hanger et al. 1999). Although bedrails have traditionally been recognized as a safety device that reduces patient falls, the study indicates that bedrails increase the severity of fall-related injuries. However, it should be noted that bedrail reduction coincided with staff training in alternatives for bedrails, such as nightlights, regular toileting regimens and treatment for delirium when bedrails were removed. This suggests that bedrail reduction programmes should be implemented along with appropriate alternative strategies for preventing falls, namely, patient consultation and staff education.

Single care process and culture-related single interventions

Medication review and modification
A retrospective before-and-after study that examined the medical records of 400 patients in one large urban rehabilitation hospital in the US found that the pharmaceutical intervention reduced falls by 47% \((30\text{ in pre-intervention vs. 16 in post-intervention, } P = 0.05)\) (Haumschild et al. 2003). The study included the following interventions: reviewing all medications, listing medications associated with dizziness, falls or fractures, educating nursing personnel on precautions for drug administration and recommending medication frequency or dosage reduction resulting from collaboration among doctors.

Identification bracelets
A 1-year randomized trial involving 134 high-risk patients in a rehabilitation hospital in Canada found that the single intervention of identification bracelets was of no benefit in reducing falls among high-risk patients (Mayo et al. 1994). In the intervention group (with blue bracelets), 27 patients \((41\%)\) fell at least once whereas in the control group (with no bracelets) 21 patients \((30\%)\) fell at least once, yielding a hazard ratio of \(1.3 \text{ [95\% confidence interval (CI): 0.8–2.4]}\). This finding may suggest that simple awareness or a warning may not sufficiently reduce the number of falls. Thus, the decreased risk of falling necessitates other intervention strategies.

Vitamin D and calcium supplementation
Vitamin D and calcium supplementation over a 12-week period effectively reduced falls among long-stay geriatric patients (Bischoff et al. 2003). This double-blind randomized controlled trial involving 122 elderly women in Switzerland found that the vitamin D plus calcium supplementation significantly improved the musculoskeletal function of this group \((P = 0.0094)\) and accounted for a 49% reduction in falls \((P < 0.01)\). However, the calcium-only group did not show a significant decrease in the number of falls. Since this is the only available study that tested this intervention, further studies that ascertain the efficacy of this strategy on geriatric patient populations and other hospital patient populations are needed.

Exercise
An exercise programme in addition to a hospital-wide multifaceted fall prevention programme in a sub-acute hospital setting in Australia effectively reduced the number of falls (Haines et al. 2007). This randomized controlled trial involving 173 patients found that the intervention
group suffered a significantly lower incidence of falls than their control group counterparts (control: 16.0 falls/1000 participant-days; intervention: 8.2 falls/1000 participant-days; log-rank test: $P = 0.007$). In contrast, a 9-month randomized $2 \times 2$ controlled trial of 54 consecutive patients in an elderly care rehabilitation ward in the UK found no statistically significant reduction in falls but observed a clinical tendency towards a reduction in falls in the experimental group (additional exercise; four falls) compared to the control group (only conventional physiotherapy; seven falls) (relative risk: $0.21$, 95% CI: 0.04–12, $P = 0.12$) (Donald et al. 2000). The findings suggest that an exercise programme may be effective only when implemented as part of a multifaceted intervention. However, both studies presented some limitations in the study design and analysis necessitating further study. The former did not adequately adjust the possible impact of a patient-sitter programme introduced only to the experiment group in the analyses. The latter, as discussed earlier (carpeted flooring), presented a small sample size with limited sensitivity to the outcome measures.

**Patient education**

A randomized controlled trial involving the subgroup ($n = 226$) of the larger randomized controlled trial ($n = 626$) (Haines et al. 2004) in a sub-acute hospital setting in Australia found that the intervention group (patient education programme) in this subgroup analysis had a significantly lower incidence of falls than their control group counterparts (control: 16.0 falls/1000 participant-days, intervention: 8.2 falls/1000 participant-days, log-rank test: $P = 0.007$) (Haines et al. 2006). However, it should be noted that the intervention group received the patient education programme along with a hospital-wide multifaceted fall prevention programme. That is, the patient education programme may not be effective in isolation. In addition, the intervention should be applied to appropriate patient populations such as those with no severe communication or learning impairment.

**Volunteer companion programme**

One 19-month before-and-after study in a geriatric acute care ward in Australia observed a statistically significant decrease (44%) in the fall rate per 1000 bed days ($P < 0.000$; OR: 0.56, 95% CI: 0.45–0.68) (Donoghue et al. 2005). According to findings of the first 4 months of the implementation period (1 August–17 December 2002), the study showed that no falls occurred when volunteers were present. Another 4-month before-and-after study in medical wards in South Australia found that volunteers played an important role in preventing falls and that no patient falls occurred when volunteers were present (Giles et al. 2006). The studies, however, emphasized the importance of appropriate volunteer training and on-going education in maintaining the efficacy of the intervention.

**Single technology-related interventions**

**Bed alarm system**

Despite observing a clinical tendency towards fall reduction, studies investigating the efficacy of a bed alarm system did not observe a statistically significant reduction in the number of falls (Tideiksaar et al. 1993, Diduszyn et al. 2008). A 9-month case-controlled study with 70 increased-risk patients at a geriatric evaluation unit at a teaching hospital in the US found only a slight reduction in bed falls between the control ($n = 4$) and experimental group ($n = 1$) (Tideiksaar et al. 1993). A recent 4-month before-and-after study on one neurology and three telemetry floors of a 500-bed acute care university hospital in the US showed a reduction in the number of falls (78 in baseline vs. 64 in implementation) when nurses carried an advanced alarm system with a portable beeper that they could hear clearly (Diduszyn et al. 2008). However, without controlling for other important factors (e.g. patient census and characteristics) affecting the number of falls, the efficacy of this intervention is open to debate.

**Environment-related research**

**Unit and patient room design**

A 4-month prospective observational study involving 1609 patients at three acute medical wards in the UK investigated patient and ward characteristics (e.g. ward layouts) associated with falls (Vassallo et al. 2000). The three acute medical wards, distinctly different in their structural layouts, offered different ranges of visual access to a patient’s bed. While a 40-bed longitudinal layout ward (A) had only 20% of beds visible from nursing stations, a 40-bed (B) and a 28-bed (C) nuclear layout ward had 85%. The study found that the former was associated with a significantly higher number of falls and fallers than the latter: 31 (A) vs. 18 (B)/14 (C) falls ($P = 0.01$) and 27 (A) vs. 13 (B)/12 (C) fallers ($P = 0.001$, OR: 2.54, 95% CI: 1.41–4.57). Among the three, no important differences had been found in ward turnover rates, mortality rates and diagnostic groupings of patients. This study showed that their layout characteristics were important independent risk factors for falls, even when controlling for gender, age and mortality through logistic regression analysis. A before-and-after study utilizing data from 2 years prior and 3 years after a renovation at the Methodist Hospital and
Clarian Health Partners in the US investigated the impact of a unit layout on several process and patient outcomes such as transfers, falls and medication errors (Hendrich et al. 2004). The study reported that when the hospital changed its coronary intensive care units from two-bed rooms to acuity-adaptable single-bed rooms with decentralized nurse stations, patient transfers decreased by 90%, falls by 67% and medication errors by 70%. Both reductions in transfers and increases inpatient visibility appear to be associated with a reduction in falls.

**Flooring**

Two laboratory experiments found that greater floor compliance (softness) increased postural sway in healthy older participants (Redfern et al. 1997, Dickinson et al. 2001). One suggested that floors with minimum softness, including uncarpeted (e.g. vinyl) or carpeted floors without padding, were associated with a lower risk of falling. The other found that, compared to the firm surface with no carpet or padding, a particular commercial-grade carpet did not increase postural sway (Dickinson et al. 2002). Ultimately, the randomized 2 x 2 controlled trial of 54 consecutive patients conducted by Donald et al. (2000), as discussed earlier (carpeted flooring), found that more falls occurred on carpeted floors (ten) than on vinyl floors (one) (P = 0.05).

Softer floors may reduce the severity of injuries (e.g. hip fractures) by applying lower forces to the hip during a fall (Laing et al. 2006, Sran & Robinovitch 2008). A retrospective study that analysed a sample of 225 fall accident forms over 4 years, selected at random, in an elderly care unit in the UK found that patients who fell on carpeted floors were less likely to sustain injury than those who fell on vinyl flooring (Healey 1994). It was found that while 46% of patients who fell on vinyl floors sustained injuries, only 17% of patients who fell on carpeted floors sustained injuries. Another 2-year prospective cohort study conducted at 34 residential care homes in the UK found that of all the floor types (i.e. uncarpeted with wooden sub-floors, carpeted with concrete sub-floors and uncarpeted with concrete sub-floors), carpeted floors with wooden sub-floors were associated with the lowest number of fractures per fall (odds ratio: 1.78, 95% CI: 1.33–2.35) (Simpson et al. 2004). To achieve both a lower incidence of hip fractures and better balance, we must conduct further studies that determine the optimal degree of softness of a floor and a proper flooring type.

**Multi-systemic fall prevention model**

The two multi-systemic fall prevention models emphasize the synergic effects of a multi-systemic approach that acts upon the three domains of hospitals (i.e. the physical environment; the care process and the culture; and technology) in preventing falls and injuries (Figures 2 and 3) and facilitates the understanding of the detailed mechanisms of individual fall prevention interventions that lead to a reduction in falls and injuries (Figure 2). In this model (Figure 3), environment, care process- and culture-, and technology-related interventions or factors associated with falls and injuries are presented on the left and linked to their mechanisms and outcomes of interest (e.g. reducing falls and injuries) on the right. Asterisks represent the strength of evidence supporting each intervention: (1) One asterisk (*) denotes an intervention or a factor whose efficacy was NOT tested as a single factor in any healthcare setting; (2) two asterisks (**) represent an intervention or a factor whose efficacy was tested as a single factor in other healthcare settings but not specifically in a hospital setting; and (3) three asterisks (***) denote an intervention or factor whose efficacy was tested as a single factor in a hospital setting.

**Discussion**

The results of the study indicate that hospitals often employ two broad strategies to fall prevention. The most frequently used approach is to implement care process- and technology-related interventions targeting at-risk patients by evaluating a patient’s risk of falling and modifying his/her individual fall risk factors. This includes two of the three systems identified above: care process and technology. The other approach is to give a safe and supportive environment that allows better visual access and closer proximity to patients and includes few or no environmental hazards and more assistive devices for patients, family members and staff. Such environmental features help mitigate falls, assist patients during activities and also facilitate prompt staff monitoring and the detection of alarming patient movements before they lead to falls.

Despite clinically significant evidence that supports the importance of the physical environment in preventing falls, only a few hospitals have been identified in the literature as introducing environment-related interventions (e.g. environmental assessment and modification) as part of their multi-faceted fall intervention strategies. Most implemented a considerable number of care process-related interventions that may demand time and effort from nurses to ensure their effectiveness, which could be undermined by low compliance.

While some care process and technology interventions can be demanding on staff, some environment-related interventions could actually facilitate staff jobs. Studies suggest that certain unit layouts (i.e. acuity-adaptable
patient rooms with decentralized nurses’ stations and nuclear layout units) increase staff visibility and proximity to patients, which would allow nurses to easily detect any risky patient movements and facilitate their response to a patient in a timely manner. In addition, supportive design features introduced by environmental assessment and modification interventions (e.g. secured handrails throughout patient movement paths and non-slip flooring) would reduce the risk of falls by assisting patients during various activities.

This review has several limitations. First, two independent reviewers were not involved in the processes of the study selection, quality appraisal and data extraction. One primary reviewer was involved in these processes under the supervision of another reviewer in the study. Second, no studies were excluded after the appraisal process. Both limitations mentioned above may have increased the risk of bias in the review. In addition, due to the heterogeneity of interventions and outcome measures, a meta-analysis of pooled results could not be conducted. Thus, the findings were described narratively. Another limitation was that no papers in languages other than English were included, which may limit the generalizability of the findings. The search strategy was also limited to electronic databases, and so publication bias could not be excluded. Moreover, generalizability may also have been sacrificed because qualitative evidence was excluded from the review. As the model in this study includes only quantitative evidence, another model that also includes qualitative evidence would give a richer source of information that hospital executives and nursing administrators could access to address complex questions and issues involving the care practice, interventions and the impact of the interventions on care providers and patients in relation to fall prevention. Finally, the efficacy of the proposed model should be validated in future studies that establish a structured strategy of incorporating lessons-learned through testing, transforming and integrating the model in clinical practice guidelines.
Figure 3 Multi-systemic fall prevention model. (a) Firm mattresses; low beds; appropriate chair heights and depths for easy transfer; chairs with arm rests; and secured handrails throughout the movement of a patient. (b) Non-slip surfaces in floors/bathubs; shower seats; grab bars next to the toilet/bathtub; toilet seats that allow easy transfer; door magnets that hold doors in the open position; and arm rests next to the toilet. * An intervention or a factor whose efficacy was NOT tested as a single factor in any healthcare setting. ** An intervention or a factor whose efficacy was tested as a single factor in other healthcare settings but NOT specifically in a hospital setting. *** An intervention or factor whose efficacy was tested in a hospital setting.
Conclusions

Implications for research

While identifying clinically significant evidence that demonstrated the effects of the physical environment on falls, fall-related injuries and intermediate patient outcomes associated with falls (i.e. postural sway and hip impact force), well-documented empirical studies that test the relationships between the physical environment and falls and fall-related injuries were very limited. Many of the articles were excluded from this study because they did not meet the inclusion criteria even though they offered an overview of environmental factors and underlying mechanisms that link the environment to such outcomes.

Several environmental factors have shown promise at reducing falls or fall-related injuries: (1) Nuclear unit layouts and acuity-adaptable rooms with decentralized nurses’ stations relate to a reduction in the number of falls; and (2) carpeted flooring and carpeted flooring with wooden sub-flooring correlate with a decline in the severity of fall-related injuries. These conclusions apply both to new construction and to hospitals facing the replacement or renovation of their ageing facilities. Further studies are needed that establish a structured process model that can guide hospital executives and nursing administrators to incorporate certain environmental factors during certain stages of hospital planning and construction.

Several hospitals have implemented easy-to-apply interventions (e.g. the relocation of at-risk patients close to nurses’ stations and identification bracelets) as part of their multifaceted strategies (See supporting information Table S3 in the online version of the article in Wiley online Library), but the review identified no solid evidence demonstrating the efficacy of such individual interventions on the reduction of falls and injuries. On the other hand, although it identified clinically significant evidence of the efficacy of some interventions (e.g. medication review/modification and volunteer programmes) at reducing falls in related settings, it found that they have not been widely adopted in hospitals.

This review identified several effective single interventions that hospitals should consider as part of their multifaceted fall prevention intervention: (1) medication review and modification, (2) patient education, (3) volunteer programmes and (4) bedrail reduction programmes; and it clarified the need for further studies that could give conclusive evidence on the efficacy of specific single interventions (i.e. environmental assessment/modification, hip protectors and footwear) that have proven effective in reducing the falls and injuries of long-term care or community-dwelling elderly populations but not of hospital inpatient populations.
Implications for nursing practice

A multi-systemic fall prevention strategy that takes into account the benefits of physical environment-related interventions/factors in fall prevention could more efficiently address both intrinsic and extrinsic/environmental fall risk factors and therefore prevent falls and assure a safe and supportive environment that is not only efficacious to fall prevention but also beneficial to the well-being of patients and caregivers. Thus, hospitals need to recognize the important role of the physical environment in fall prevention and incorporate environment-related interventions into their multifaceted fall prevention intervention programmes. The multi-systemic fall-prevention models can assist hospital executives and nursing leaders with the development of a balanced fall prevention strategy that benefits from the collective effects of the physical environment, the care process and culture and technology to prevent falls and fall-related injuries. The acquired evidence base in the efficacy of environment-related interventions/factors will be useful to many hospital executives and nursing administrators as they go through different stages (e.g. the new construction, renovation, or replacement) of hospital planning and construction.

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Conflict of interest

No conflict of interest has been declared by the authors.

Author contributions

YC, CB, EP and CZ were responsible for the study conception and design. YC performed the data collection. YC performed the data analysis and was responsible for the drafting of the manuscript. CB, EP and CZ made critical revisions to the paper for important intellectual content. CB, EP and CZ obtained funding. CZ gave administrative, technical or material support. CZ supervised the study.

Supporting Information Online

Additional Supporting Information may be found in the online version of this article:

Table S1. Search strategy.
Table S2. Quality appraisal of studies.
Table S3. Individual components of multifaceted interventions in hospital.

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References


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