Health Environments Research & Design Journal

The SCOPE of Hospital Falls: A Systematic Mixed Studies Review

Journal:	*Health Environments Research & Design Journal*
Manuscript ID	HERD-16-0012.R2
Manuscript Type:	Literature Review
Keywords:	Human factors, Inpatient hospitals, Patient safety, Patient falls, Systematic literature review, Environmental design, Evidence-based design

Abstract:	PURPOSE: This systematic mixed studies review (MSR) on hospital falls is aimed to facilitate proactive decision-making for patient safety during the healthcare facility design. BACKGROUND: Falls were identified by CMS as a non-reimbursed hospital acquired condition (HAC) due to volume and cost, and additional financial penalties were introduced with the 2014 US hospital acquired condition (HAC) reduction program. A 2015 alert identifies patient falls as one of the top reported sentinel events reported to the Joint Commission. Variations in fall rates at both the hospital and the unit level is indicative of an ongoing challenge. The built environment can act as a barrier or enhancement to achieving the desired results in safety complexity that includes the organization, people and environment (SCOPE). METHODS: The systematic literature review used MeSH terms and key word alternates for hospital falls with searches in MEDLINE, Web of Science, and CINAHL. The search was limited to English-language papers. RESULTS: Following full text review, 27 papers were included and critically appraised using a dual method mixed methods critical appraisal tool. Themes were coded by broad categories of factors for organization (policy/operations), people (caregivers/staff, patients); and the environment (healthcare facility design). Subcategories were developed to define the physical environment and consider the potential interventions in the context of relative stability. CONCLUSIONS: Conditions of hospital falls were identified and evaluated through the literature review. A theoretical model was developed to propose a human factors framework, while considering the permanence of facility design solutions.

ABSTRACT

Purpose

This systematic mixed studies review (MSR) on hospital falls is aimed to facilitate proactive decision-making for patient safety during the healthcare facility design.

Background

Falls were identified by the Centers for Medicare & Medicaid Services (CMS) as a non-reimbursed hospital acquired condition (HAC) due to volume and cost, and additional financial penalties were introduced with the 2014 US hospital acquired condition (HAC) reduction program. In 2015, a Joint Commission alert identified patient falls as one of the top reported sentinel events, and the Occupational Safety and Health Administration (OSHA) added slips, trips, and falls as a focus for investigators' healthcare inspections. Variations in fall rates at both the hospital and the unit level is indicative of an ongoing challenge. The built environment can act as a barrier or enhancement to achieving the desired results in safety complexity that includes the organization, people and environment (SCOPE).

Methods

The systematic literature review used MeSH terms and key word alternates for hospital falls with searches in MEDLINE, Web of Science, and CINAHL. The search was limited to English-language papers.

Results

Following full text review, 27 papers were included and critically appraised using a dual method mixed methods critical appraisal tool. Themes were coded by broad categories of factors for organization (policy/operations), people (caregivers/staff, patients); and the environment (healthcare facility design). Subcategories were developed to define the physical environment and consider the potential interventions in the context of relative stability.

Conclusions

Conditions of hospital falls were identified and evaluated through the literature review. A theoretical model was developed to propose a human factors framework, while considering the permanence of solutions.

Background

A significant number of patients are falling, many sustaining injury that sometimes results in death (Bouldin et al., 2013; Donaldson, Panesar, & Darzi, 2014; National Patient Safety Agency [NPSA], 2010; Staggs, Mion, & Shorr, 2014). Hospital staff are also subject to slips, trip, and falls (STFs). The U.S. Bureau of Labor Statistics (BLS) data indicated the incidence rate of lost-workday injuries from STFs was 90% greater than the average incidence rate for all other private industries combined (BLS, 2009, as cited in Bell, Collins, Daley, & Sublet, 2010). As the population of baby boomers ages, reports estimate that this overall aging demographic will experience an increase in falls (Cigolle et al., 2015; Kandel & Adamec, 2009). One study found the rate of falls for adults 65 and older in the US increased by 8.1% between 1998 and 2010 (Cigolle et al., 2015).

In the US, hospital falls emerged as a safety focus following non-reimbursement of certain hospital-acquired conditions (HACs) as part of the Deficit Reduction Act of 2005 (Centers for Medicare & Medicaid Services [CMS], 2008); additional financial penalties introduced as part of the U.S. Hospital-Acquired Condition Reduction Program (HACRP) in 2014 (CMS, 2013); a recent alert that identifies falls with serious injury as one of the top 10 reported sentinel events (The Joint Commission, 2015); and an Occupational Safety and Health Administration (OSHA) that emphasized a focus on STFs in investigators' healthcare inspections (Occupational Safety & Health Administration, 2015). Even as the inpatient falls and trauma rate in the US decreased by nearly 15% between 2010 and 2013 (U.S. Department of Health & Human Services, 2014), large variations in the fall rate at both the hospital and the unit level are indicative of an ongoing challenge of controlling for this adverse event (He, Dunton, & Staggs, 2012). Moreover, inpatient fall rates with injury are rising in other countries (Jorgensen et al., 2015).

The risk of falls is often categorized by intrinsic and extrinsic factors (Calkins, 2012; Tzeng, 2008), with most falls associated with intrinsic factors (Hendrich, 2006). Intrinsic risk factors (such as age, weight, a prior fall, and gender) are integral to each individual (Schaffer et al., 2012; Tzeng & Yin, 2008; Vassallo, Azeem, Pirwani, Sharma, & Allen, 2000), while extrinsic factors are the external conditions including physical environmental factors, as well as staff communication, risk assessments, medications, care planning, and unavailable or delayed care provision (Choi, Lawler, Boenecke, Ponatoski, & Zimring, 2011; Healey, 1994; Schaffer et al., 2012; Tzeng & Yin, 2008; Vassallo et al., 2000). While one author reported 10-15% of falls were caused by the environment alone (Hendrich, 2006), Joint Commission data for voluntarily reported sentinel events for 2004-2015 indicated 41.6% of falls had a root cause in the physical environment (The Joint Commission, 2016). With respect to extrinsic factors, there is a lack of research to systematically examine environment-related interventions for falls in hospital settings (Calkins, Biddle, & Biesan, 2012; Choi et al., 2011), and most falls researchers do not include building features as discrete variables (Gulwadi & Calkins, 2008). The lack of research creates a challenge for the healthcare facility design team, and the patient- and staff-related outcomes of some decisions will be felt for decades.

In the United Kingdom (UK), clinical guidelines state the necessity for multifactorial interventions, including the need for research addressing adaptations of the environment "that have plausible mechanisms for reducing falls in patients" (National Institute for Health and Care Excellence [NICE], 2013, p. 17). However, multifactorial (bundled) approaches make it difficult to quantify the effect of any particular intervention. With this complexity in mind, a systematic mixed studies review was conducted to understand the range of conditions and interventions associated with hospital falls. While the focus of peer-reviewed literature is patient falls, the reported incidence of staff falls in hospitals also contributes to an understanding of the risks and interventions to benefit all users of acute-care facilities. There were two aims and phases of the review. The first aim was to explore and appraise aspects of the built environment that contribute to or mitigate the risk of falls in hospitals. The second was to capture non-built environment conditions contributing to falls and falls risk mitigation to further a systems approach to understanding falls prevention.

Methods

The search included English language full-text studies meeting the following criteria: conducted in a hospital (acute care) setting; risk factors (correlations) or interventions related to hospital falls and/or falls with injury; qualitative and/or quantitative results (a mixed methods approach); and patients (adult and pediatric) or staff. Studies that only reported intermediate outcomes such as incontinence, gait or postural sway were excluded, as were community- or home-based falls, and falls in long-term care settings. Exclusion criteria also included regulatory codes, legislative directives, or industry guidance for best practice. Three databases were used (Medline, CINAHL, and Web of Science), supplemented by The Center for Health Design Knowledge Repository (https://www.healthdesign.org/knowledge-repository). Key words were assembled from Medical Subject Headings (MeSH) terms and other terms found in known falls papers (Table 1). The primary outcomes of interest were rates, reductions, or increases in falls or falls with injury. Outcomes with identified factors contributing to falls and possible interventions derived from qualitative analysis were also included. [INSERT TABLE 1].

Five literature reviews identified through the search parameters were included to identify any additional physical environment conditions not found in single studies returned through the search. The original sources were retrieved and evaluated for inclusion based on the stated search criteria. To avoid citation duplication or secondary citations, the literature reviews were not included in the final thematic analysis. Titles and abstracts were screened for duplication and reviewed for relevance. The remaining full texts were reviewed before inclusion.

Data for single studies were extracted and analyzed using NVivo 10 (QSR International, 2012). Extraction included population, sample size, study duration, setting, interventions, and outcomes. Due to a lack of consistency in reporting, a lack of homogeneity in outcomes, and the mixed methods nature of the review, a thematic analysis for a narrative synthesis was conducted to explore the main themes and identify the range of factors within and across the included studies (Mays, Pope, & Popay, 2005; Popay et al., 2006). A thematic analysis is particularly suited to a systematic review with diverse evidence (Popay et al., 2006).

Results

Search Flow and Appraisal

The search flow is illustrated in Figure 1. [INSERT FIGURE 1]

A matrix method for appraisal was used to evaluate the level of evidence and the methodological quality (Taylor & Hignett, 2014). Most of the studies were categorized in a mid-range “level” of evidence with a mid to high methodological strength of the study (Figure 2). The most common missing component of the papers was sufficient patient demographics to evaluate whether pre- and post-test groups were comparable (Barker, Kamar, Tyndall, & Hill, 2013; Brandis, 1999; Calkins et al., 2012; Healey, 1994; Mosley, Galindo-Ciocon, Peak, & West, 1998; Ohde et al., 2012; Wolf et al., 2013). In other studies it was not possible to determine whether the sample was representative of the population (Goodlett, Robinson, Carson, & Landry, 2009; Gutierrez & Smith, 2008; Lopez, Gerling, Cary, & Kanak, 2010; Mosley et al., 1998; Vieira et al., 2011) or whether the data collection tool or measures were clearly validated (Gowdy & Godfrey, 2003; Krauss et al., 2008; Mosley et al., 1998; Schaffer et al., 2012).

[INSERT FIGURE 2]

In a small number of studies, attrition rates were high (Cozart, 2009; Donald, Pitt, Armstrong, & Shuttleworth, 2000), outcome data was not 80% complete (Krauss et al., 2008), and site selection may have been subject to bias (Calkins et al., 2012). In qualitative studies, it was not always possible to tell whether the sources of qualitative data (i.e. informants) were representative of the study sites (Dykes, Carroll, Hurley, Benoit, & Middleton, 2009; Gutierrez & Smith, 2008), how the data were analyzed (Gutierrez & Smith, 2008), or how the researcher may have influenced the study through their own interactions (Vieira et al., 2011).

While all of the studies were conducted in inpatient settings, there was a range of hospital and unit types. Study timeframes also varied dramatically from as few as three months to as many as 11 years. Five studies evaluated the characteristics and risk factors of falls without intervention (Calkins et al., 2012; Hitcho et al., 2004; Schaffer et al., 2012; Tzeng & Yin, 2008; Vieira et al., 2011). As shown in Figure 3, fewer than half of the included papers reported some aspect of their results with statistical significance (e.g. falls, injury), while six studies reported outcomes that did not reach statistical significance (Brandis, 1999; Cozart, 2009; Donald et al., 2000; Goodlett et al., 2009; Shorr et al., 2012; Warren & Hanger, 2013). Three studies reported outcomes without reporting whether there was statistical significance (Gowdy & Godfrey, 2003; Gutierrez & Smith, 2008; Wayland, Holt, Sewell, Bird, & Edelman, 2010). Four studies that reported a decrease in falls with injury also found an increase in the overall rate of falls (Barker et al., 2013; Drahota et al., 2013; Shorr et al., 2012; Warren & Hanger, 2013). This increase was only statistically significant in one study (Barker et al., 2013). [INSERT FIGURE 3]

Considering Falls as a Systems Issue

There are often challenges in fully understanding a problem being solved, especially in the area of healthcare safety where the larger multi-factorial conditions might be missed (Henriksen, 2011). The potential for an incomplete understanding is especially true for hospital falls where there is rarely a single cause for a fall. A key message in patient safety has emphasized error as a systems problem, while identifying human factors/ergonomics as an important component of the solution (Carayon, 2011; Institute of Medicine [IOM], 1999, 2001). **Taking a systems approach using human factors/ergonomics, the results of the review synthesis were broadly categorized as the organization (operations, policies, and procedures), people (staff, caregivers, and patients), and the environment**. While there may not be a direct correlation to any particular intervention within a bundle and the overall quality of the study, identifying the frequency of an intervention (vote counting) can illustrate preliminary patterns across studies (Popay et al., 2006). As bundles rarely comprise the same set of interventions, patterns serves as a useful method to analyze, synthesize findings, and lastly gauge the possible "weight" behind particular solutions, even if not intended as a more definitive conclusion that might result from a meta-analysis.

The Environment: The Setting for all Activities

Environment can have different meanings in human factors/ergonomics studies and for this review, four subset "components" were defined from the literature (Carayon, Alvarado, & Hundt, 2007; Karwowski, 2012; Wilson & Corlett, 2005). These include:

- the workspace envelope (WE) as the wider workplace including the building characteristics, adjacencies, and space constraints;
- personal workspaces (PW) that include the layout of the staff or patient "workstation" or immediate area of use, including the relationship of equipment, furniture, and controls to the user (including anthropometrics);
- products (Pr), such as the selection/specification of equipment, furniture, or controls; and
- the ambient environment (AE) - addressing thermal, air, noise, and illumination considerations.

Risk factors (correlates) for falls. As previously described, the risk of falls is most often described through underlying intrinsic factors (integral to the individual) or extrinsic factors (external to the individual). As there is rarely a single cause of a fall (The Joint Commission, 2016), multifactorial solutions to prevent falls focus on mitigating the underlying conditions correlated to falls and falls with injury (Calkins, 2012). Understanding the correlates of falls is important to best determine interventions, especially where the built environment may create a latent condition for a risk of falls (e.g., visibility). Not all of the reviewed studies included an analysis of the correlates of falls within their own study or organization, especially correlates of the environment. In most cases, investigators drew upon the literature to identify the issues to consider in a falls prevention program. Those studies that investigated specific correlates included a variety of conditions pertaining to the physical environment, the organization (operations, policy, and procedures), and people (staff, caregivers, and patients).

Extrinsic risk factors of falls correlated with the environment identified in the included studies are summarized in Table 2. [INSERT TABLE 2]

With respect to environmental risk factors, two studies (Calkins et al., 2012; Wolf et al., 2013) found rooms with direct visibility or close proximity from nurse stations were correlated to higher rates of falls, but the authors of both studies indicated the higher rates may have been a result of the highest risk patients being placed in those rooms. Underlying factors of bathroom location were inconsistent. In one study where bathrooms were located on the headwall (presumably closer to the bed), there were obstacles in the patient path, including a sink outside of the bathroom (Wolf et al., 2013). A second study reported (with surprise) there were more falls when the bathroom was located on the headwall (Calkins et al., 2012), and a third referenced patient disorientation to bathroom location as a contributing factor (Mosley et al., 1998). Two studies considered the correlation between falls and the distance to the bathroom. There were no details about the physical location (Tzeng & Yin, 2008) and no statistical significance when the bed was closest to the bathroom (Krauss et al., 2008).

Interventions identified in the review were organized according to the aforementioned human factors/ergonomics physical environment categories: WE, PE, Pr, and AE. Citations are referenced by study number as defined in Figure 2 (the appraisal matrix) and Figure 3 (intervention quantities and study results).

WE. Interventions in the WE include family presence, visual cues, clearing clutter, flooring, unit layout, and other considerations.

Family Presence. Ten studies of varying quality appraisal referenced the importance of family presence in a falls prevention program (Figure 4). Family presence interventions included education and awareness, but also entailed family staying with the patient (Gutierrez & Smith, 2008; Krauss et al., 2008; Mosley et al., 1998) and assisting where possible (Ohde et al., 2012; Tzeng & Yin, 2008). This finding implies the need for space for family to stay 24/7, a feature often included in more recent patient room designs. One study noted that families were a difficult aspect to control as participation was voluntary (Tzeng & Yin, 2008). Another study found that while relatives should be involved, family members had little to add in a conversation about falls, raising a concern that they do not perceive fall prevention as their role (Vieira et al., 2011). This misaligned expectation highlights the need for a proactive and active partnership, referenced by Wolf et al. (2013) and family engagement that extends beyond mere physical presence. Half of the studies referencing family presence reported statistically significant results as part of the overall study. [INSERT FIGURE 4]

Visual cues. Visual cues in the WE category addressed communication breakdowns and were incorporated in 10 of the included studies, most in the mid-range of quality appraisal and half of which reported statistically significant outcome results (Figure 4). Visual cues often included hallway signage for patient rooms that incorporate color or a graphic, such as falling leaf or falling star (See Figure 4 for citations). One study did not specify the location of visual cues (Schaffer et al., 2012). Hallway signage was often part of a set of visual cues that also included signage inside the room and/or colored patient wrist identification bracelets used to visually alert staff (and family) to a patient's fall risk.

As identified in Figure 4, numerous studies also referenced visual cues through posters to educate both staff and families about prevention programs (Brandis, 1999; Dykes et al., 2009; Mosley et al., 1998; Ohde et al., 2012; Wolf et al., 2013). Materials in one study included photographs to portray correct applications of the intervention bundle (e.g., signs, armbands, hip protectors) (Brandis, 1999). Some study participants believed an education strategy was especially important for nurse assistants who were less likely to receive the most recent patient report communication (Dykes et al., 2009). However, according to the authors, a lack of necessary detail about the fall risk and recommended actions (perhaps best communicated through pictograms), along with a sense of visual overload, made visual information less effective.

Clearing clutter. While a reference may have been generic to suggest a clutter-free environment (Gutierrez & Smith, 2008), clutter was defined in several papers as keeping floors and walkways clear of objects (Bell et al., 2008; Gowdy & Godfrey, 2003; Krauss et al., 2008); ensuring a clear path around the bed (Fonda et al., 2006); ensuring unobstructed access to the bathroom (Dykes et al., 2009; Tzeng & Yin, 2008); and removing items not being used from the unit/ward (Healey, 1994). The need for storage was supported by feedback from patients, families, and staff that additional storage was required (for patient personal items, as well as medical equipment) and that objects and equipment should be returned to their proper place when not in use (Vieira et al., 2011). Vieira et al. also articulated a staff concern that crowding from furniture or conflicts with door swings in the patient's path of travel should be considered. The studies referencing clutter-free spaces spanned a range of appraised quality and while not all of the reviewed papers reported significant outcomes, managing the clutter was also deemed a "common-sense" intervention by participants in one study (Dykes et al., 2009).

Flooring. Fonda et al. (2006) generically cited the need for non-slip flooring in the bathroom (a code requirement in many countries), and although same-level changes between flooring materials are also regulated in some countries (ADA Standards for Accessible Design, 2010), one study referenced eliminating such height discrepancies (Ohde et al., 2012). However, several other studies empirically investigated specific flooring materials and the implications of fall rates or falls with injury when comparing one flooring material to another. Although flooring studies generally required some form of renovation or construction and were therefore less referenced within the many bundled interventions, the studies that investigated such comparisons were generally of a higher quality appraisal.

The most studied comparison was carpet and vinyl (Donald et al., 2000; Healey, 1994; Warren & Hanger, 2013), but the results were not consistent and did not always include statistically significant results. In Healey's retrospective study (1994), the analysis of four years of accident forms revealed there were no more falls on carpet than on vinyl, but the incidence of injury from falls was lower on the carpeted floors than on vinyl (15% on carpet as compared to 91% on vinyl). Donald et al. (2000) found more patients fell on the carpet floor than vinyl, but the results were not statistically significant and the time period was relatively short (nine months). Additionally, the small number of falls on vinyl made comparison of injury impossible. The third study (Warren & Hanger, 2013) found no significant difference in fall rates between the two materials in pre- and post-comparison, but also found these findings varied by ward type. There were non-significant trends of lower fall rates on carpet in some wards (stroke and general wards), but a statistically significant higher rate of falls on carpet in the psychiatric ward over the year prior and following the installation of new flooring.

In a pilot cluster randomized control trial, Drahota et al. (2013) compared a specialized sports flooring applied over concrete subfloor to in situ flooring (on concrete subfloor) at eight sites in the bed areas. The results indicated this shock-reducing flooring may reduce injuries, but may have also increased the overall risk of falling. The study also found tradeoffs relative to the rollability of the surface from a staff perspective. It should be noted industry guidance is available to assess forces for pushing and pulling tasks (Liberty Mutual Research Institute for Safety, n.d.), and this floor type is not recommended by the manufacturer for an acute-care setting.

Unit layout. In one natural experiment of three unit types, authors found the nuclear layouts in two units (where 85% of patient beds were visible from either one or two nursing stations) contributed to a significantly lower number of falls than on a unit with visibility of only 20% of the patient beds (Vassallo et al., 2000). **Optimizing unit layout often pertained to visibility but the layout may have also affected nurses' and other caregivers' cognitive load contributing to risk factors for patient safety.** Lopez et al. (2010) referenced functional adjacencies, noting that when the location of functions such as medication preparation and charting precluded ongoing surveillance of patients, workarounds occurred. The authors suggested that design strategies should relocate indirect care tasks closer in physical proximity to the bedside. While most studies did not offer details about locations of nursing stations or primary activities, one study established satellite nursing stations outside patient rooms (Gutierrez & Smith, 2008). Another consideration for improved visibility to the patient and/or the patient bathroom, was the ability to leave doors open, which was referenced in two less rigorous studies (Gowdy & Godfrey, 2003; Gutierrez & Smith, 2008). Maintaining privacy, however, was recognized as a conflicting consideration in improving visibility to the toilet (Gutierrez & Smith, 2008).

A second aspect of unit layout and workflow included storage, also discussed as part of the WE. In this instance of providing storage, the issue was locating storage for convenience and accessibility to facilitate use. Storage modifications were suggested by Vieira et al. (2011), where study participants recommended reorganizing the unit, even converting a patient room into an equipment storage area to provide easier access.

Other considerations. Patient lifts were recognized in a single study (Bell et al., 2008), that concurrently addressed both patient-handling injuries, and slip, trip, and fall (STF) injuries.

Other interventions in the WE addressed correlates in another broad category: Organization. For example, the organizational policy of maintaining clean and dry surfaces was supported in the physical environment with locations for umbrella bags and areas to store ice-melt to mitigate the risk of wet or slippery floors (Bell et al., 2008). Temporary beveled-edge walk-off mats were also suggested, but in new construction, a seamless transition can be achieved with an integrated recessed-style mat.

PW. Interventions in the PW included keeping items within reach, visual cues, and other considerations.

Items in reach. Ensuring the call system was within patients' reach was cited in numerous studies, and this theme was similar to one ensuring that personal items such as phones, water, over bed tables, canes, and walkers were within reach, as well as providing bedside commodes. (See Figure 4 for citations).

Visual cues. Additional PW interventions included visual cues such as falls alert or yield signage either at the bed within the patient room (Barker et al., 2013; Fonda et al., 2006; Lopez et al., 2010; Wayland et al., 2010) or on the patient whiteboard where different languages for the patient might be incorporated (Dacenko-Grawe & Holm, 2008). Details about a mobility program were also included in a whiteboard strategy (Krauss et al., 2008). Visual interventions were located both outside and inside the room (Krauss et al., 2008).

Visual cues go beyond signage, however, with one study highlighting the need to clearly identify level changes (i.e. stairs, curbs) by providing visual cues to changes in elevation with contrasting strips or contrasting/yellow warning paint (Bell et al., 2008). While the study focused on staff safety for STF, clearly marking a level change is an intervention affects everyone using the facility, including patients and families.

Other considerations. One comprehensive intervention was to fully equip specific falls-prevention rooms for high-risk patients (Calkins et al., 2012; Cozart, 2009; Gutierrez & Smith, 2008). In one study, the falls-prevention room included bed controls at fingertips, a bed alarm, a bedside commode, a non-skid floor, a non-slip floor mat, room illumination at all times, a bed trapeze, a falls prevention poster, non-exit side bed rails up for support, a split rail configuration (head rail up, foot rail down) at all times on the exit side of the bed, and a hemi-walker within reach (Cozart, 2009, p. 105). Providing a standardized room eliminated the need for organizational policies requiring nurses to determine custom interventions following a falls risk assessment. Even though one study empirically investigated falls-prevention rooms, none of the included studies referenced statistical significance in the overall study outcomes. Bedside charting was an intervention in one study, with portable computers provided for nurses to complete documentation within the line of sight to patients (Gutierrez & Smith, 2008).

Pr. Product-related interventions included alarms, furniture and other several other individually-referenced considerations.

Alarms. By far, the most prevalent of the product were the inclusion of alarms to alert staff to patient movement in the physical environment (Figure 4). The alarm intervention studies spanned a range of quality appraisal, and only six of these studies reported statistically significant results. Two of the six were significant only in a subset of the results. **The single study investigating the use of alarms empirically (Shorr et al., 2012) found that while alarm use increased, no statistically or clinically significant effects were found on fall-related events.** Alarms ranged from (1) more permanent solutions that were integrated within furniture (mostly beds) and needed to be activated and reset (Gutierrez & Smith, 2008) to; (2) more temoprary solutions that included pads/mats used under bed sheets, on chairs, or at the bedside to alert within the patient room (Dacenko-Grawe & Holm, 2008; Lopez et al., 2010) or in both patient rooms and nurse stations (Shorr et al., 2012). Additional temporary measures included inexpensive motion detectors located near the floor and used in conjunction with bed alarms (Gowdy & Godfrey, 2003) or devices attached to the patient (Ohde et al., 2012).

In some of the studies, alarm types and details of use were not specified (Barker et al., 2013; Dykes et al., 2009; Fonda et al., 2006; Hitcho et al., 2004; Krauss et al., 2008; Tzeng & Yin, 2008; Vieira et al., 2011), while in other studies an algorithm for use was reported (Wolf et al., 2013). Lopez et al. (2010) identified the inconsistent use of alarms as a workaround to visibility and proximity issues, however, usability was also cited as a significant barrier (i.e., sensitivity, problematic user interfaces, difficult to hear). In some instances, alarms were used if the patient was confused, impulsive, forgetful of limitations, or unable to follow directions (Dacenko-Grawe & Holm, 2008; Gutierrez & Smith, 2008; Ohde et al., 2012).

Furniture. A second consistently referenced intervention was furniture selection – most often pertaining to low bed height. (See Figure 4 for citations.) However beds with brakes were also cited as an intervention (Hitcho et al., 2004; Tzeng & Yin, 2008). These are standard in new beds, but may not always be present or operational in older equipment. One empirical study evaluated the use of specialty low-low beds that lower to the floor and found a statistically significant reduction in falls with injury with a ratio of one low-low bed to three standard beds as compared to prior phases of the study with one low-low bed to nine or more standard beds (Barker et al., 2013).

A second aspect of the bed selection was bedrails. Some studies suggested split bed rails with the bottom part down on the exit side, offering some support but allowing patient egress (Cozart, 2009; Ohde et al., 2012; Mosley et al., 1998) while one study suggested the rails remain up (Gutierrez & Smith, 2008). Detail was not provided to define whether "up" meant a similar split rail pattern to the other reviewed studies. Mosely et al. (1998) and Ohde et al. (2012) reported statistically significant results overall in their respective studies with the split-rail configuration (foot end of the rail down). There were incidental references to two other furniture considerations such as appropriate seat height in chairs (Fonda et al., 2006) and recliners located in the hallways (Gutierrez & Smith, 2008). While not explicitly stated, hallway furnishings may have been used as rest locations during mobilization programs.

Other considerations. As shown in Figure 4, there were several other types of interventions. Additional product considerations included video surveillance or hallway mirrors to improve visibility of patients where structural limitations precluded layout changes. Several studies referenced non-slip mats at beds and chairs, and Bell at al., 2008 referenced beveled-edge walk-off mats at entrances in inclement weather. Two studies referenced the need to visually alert users to wet or slippery floors by consistently installing wet floor signs (Bell et al., 2008; Vieira et al., 2011). Wet floor signs included products that were more noticeable (i.e., 48" tall, flashing lights on top of the signs, or pop-up tent style signs) or more readily accessible (i.e., wall-mounted throughout the facility for quick and easy access to identify a wet floor) (Bell et al., 2008). While clutter might include tripping hazards, one study pertaining to staff hazards specifically cited the need to consider cord bundlers and cord containers at computers, medical equipment (including in surgical suites), and even kitchen equipment (Bell et al., 2008). The same study suggested beveled-edge protective cord covers and retractable cords in patient rooms and at nurse stations to reduce tripping hazards associated with electronic equipment.

Studies also cited permanent assistive devices such as grab bars. While grab bars are required in certain spaces by legislation (ADA Standards for Accessible Design, 2010), studies referenced the installation of additional permanent grab bars in bathrooms (Ohde et al., 2012); low-cost supplements in the bed area, such as stand-alone, portable hand rails requiring no special installation (Ohde et al., 2012); or vertical bed (egress) poles that were used to assist patients to transfer more independently (Fonda et al., 2006). (Bed poles can include full floor-to-ceiling installation or installation clamping to the bed rail or under the mattress.) While the specific locations of grab bars were not referenced, another study evaluating the correlates of falls found more falls with a single wall-mounted bathroom grab bar as compared to grab bars on each side of the toilets (Calkins, et al., 2012). Other product-related interventions included glow-in-the-dark commode seats or toilet signs (Fonda et al., 2006).

AE. Interventions in the AE included lighting and noise reduction.

Lighting. As shown in Figure 4, multiple studies of varying appraised quality included lighting as part of their bundled solution, but the intervention descriptions were not always specific. Several studies referenced the need for some form of lighting at night, whether continuous or motion activated (Fonda et al., 2006; Gowdy & Godfrey, 2003; Mosley et al., 1998; Tzeng & Yin, 2008). One study specified that patient areas should never be completely dark and that low-level lighting was safer than changes from light to dark (Healey, 1994). Others referenced the location of lighting. In one study, lights were both under the bedframe and two feet above the floor close to the bathroom (Wolf et al., 2013), and in another study night lights were located in the bathroom (Vieira et al., 2011). One staff-focused study highlighted the need for adequate lighting in all work areas, whether interior or exterior (Bell et al., 2008). While several studies incorporating lighting strategies had statistically significant results, one study investigating the built environment correlates to falls (Calkins et al., 2012) found no significant relationship between falls and lighting, night lights, or the number of lights the patient can control.

Quiet zones. With respect to noise and its relationship to falls, one study included a quiet zone (Gutierrez & Smith, 2008), but there were no further details offered, and the statistical significance of results was not reported.

Organization: Policies and Procedures

Factors associated with the organization (policies and procedures) and people (staff, caregivers, and patients) are summarized in Table 3. [INSERT TABLE 3]

Organizational interventions were categorized into themes of: patient evaluation, communication, surveillance, assistance policies, and maintenance. Figure 5 illustrates the referenced citations (as numerically identified in Figure 3), the prevalence, and the quality appraisal of identified interventions. The most cited interventions included risk assessments, customized interventions based on patient conditions, and post-fall documentation. [INSERT FIGURE 5]

Patient evaluations. Policies for patient evaluations were common within the organizational category, and while the use of risk assessments was the most prevalent, there were varying levels of methodological quality and statistical significance in the reported findings (Figure 5). Studies reporting use of medication-lab reviews to determine conditions that contribute to risk were of lower appraised quality. Studies reporting a hospital protocol for falls, while a higher level of appraisal, often did not describe policies, making the concept difficult to assess.

Studies with interventions supporting patient evaluations varied in appraisal levels and statistically significant results. Solutions included custom interventions, patient placement, segregation of high-risk populations, and others identified in Figure 5. Patient placement near the nurse station was complicated by operational factors such as bed availability (Lopez et al., 2010). Data sometimes indicated more falls happen near the nurse station, perhaps as a result of highest-risk patients being placed there (as described in WE). While a reduction in fall rates associated with universal precautions was statistically significant, injury rates were either not reported or were not statistically significant (Cozart, 2009; Dacenko-Grawe & Holm, 2008; Krauss et al., 2008; Ohde et al., 2012).

Communication. Communication about falls was written or verbal. With higher overall appraisal levels, only half of the studies citing post-fall documentation reported statistically significant results (Barker et al., 2013; Dacenko-Grawe & Holm, 2008; Fonda, Cook, Sandler, & Bailey, 2006; Healey, 1994; Krauss et al., 2008; Wolf et al., 2013). More general reporting policies (e.g., proper documentation of the care plan, shift reports, reports to management) were referenced as part of an intervention bundle, and electronic records were sometimes used to record falls and risk status (Figure 5). However, when risk status and preventive measures were not a mandatory entry in the electronic medical record and data were harder to find in free text fields, the medical record was a less reliable source of communicating for patient fall risk (Lopez et al., 2010).

Surveillance. Person-based surveillance was achieved through staff or sitters (paid or volunteer) who monitored high risk patients (Fonda et al., 2006; Gowdy & Godfrey, 2003; Hitcho et al., 2004; Krauss et al., 2008; Mosley et al., 1998; Tzeng & Yin, 2008), and patients with specific conditions such as alcohol withdrawal, mental challenge, or confusion often had sitters (Dacenko-Grawe & Holm, 2008; Mosley et al., 1998). A study with nurse staffing supplemented by technical partners (Gutierrez & Smith, 2008) found no statistically significant results in the number of patient falls, but one study reported patients perceived the need for more staff (Vieira et al., 2011).

Assistance policies. Policies of rounding for toileting supervision (Figure 5) were often used as many falls are elimination related and occurred when patients are unassisted in walking to the bathroom. Four studies of varying appraisal levels included rounding and reported statistically significant results in fall rates (Barker et al., 2013; Dacenko-Grawe & Holm, 2008; Krauss et al., 2008; Mosley et al., 1998), but reduced injury rates were only reported in one study in which the fall rate actually increased (Barker et al., 2013).

Facility maintenance. Several studies referenced maintenance of the environment to reduce falls risk through: hazard assessments; keeping floors clean and dry; preventing entry into spaces with hazardous/wet surfaces; and repairing surface irregularities such as damaged tiles, loose or buckled mats/carpeting, cracks, or holes. (Refer to Figure 5 for citations.)

People (Caregivers, Staff, and Patients)

While policies and procedures were commonly used to prevent falls in hospitals, they were affected by the compliance, knowledge, and abilities of caregivers, staff, and patients, as well as the limitations of the physical environment they occupy.

Caregivers and staff. A range of interventions related to staff included: education and awareness; teamwork; communication; and proper behavior recognition (Goodlett et al., 2009; Gutierrez & Smith, 2008). (See Figure 6.) One study found complexities with teamwork, as caregivers and ancillary staff were unsure how to help or were fearful of not knowing the patient condition and falls-related protocol (Dykes et al., 2009). Challenges in teamwork were voiced by focus group participants expressing that nurse/nurse assistant partnerships were vital, but communication barriers hindered effectiveness (Lopez et al., 2010). [INSERT FIGURE 6]

Patients. Extrinsic interventions related to patients included those applied to the patient and those to assist the patient. Visual cues such as colored patient wristbands or armbands were frequently used to identify at-risk patients (Figure 6). While visual cues primarily benefit staff, visual cues also serve as a reminder for patients and families. Other interventions applied to the patient included the use of non-slip footwear, hip protectors, or gait belts. Additional physical interventions for patients included access to assistive devices (walking aids) (Drahota et al., 2013; Gowdy & Godfrey, 2003; Hitcho et al., 2004; Krauss et al., 2008; Mosley et al., 1998; Vieira et al., 2011). Education programs (for patients and families) were also frequently referenced to influence appropriate patient behavior. However, one study found families perceived education and communication needs were only necessary between staff and patients and should be enforced through organizational policies and procedures (Vieira et al., 2011).

Discussion

It is clear from the number and prevalence of conditions and interventions outlined in this review, as well as the range of quality appraisal, there was no single or obvious prescriptive solution to prevent falls in hospitals. To optimize falls management, defining solutions to mitigate the risk of patient falls can be considered from a conceptual framework of stability (Hignett, 2013; Tzeng, 2011; Tzeng & Yin, 2008). Such a framework recognizes that education and information, along with rules and policies, have been identified as the two lowest levels within the hierarchy of intervention effectiveness, as they attempt to "fix people" and are ineffectual when used alone (Institute for Safe Medication Practices [ISMP], 1999). **According to the ISMP, the highest level of intervention, a forcing function, attempts to fix the system by designing so that an error is harder to make, and it is inherently more stable than interventions that rely on correct human actions. The design of a healthcare facility can be**

considered in some respects a forcing function. An organizational policy may include leaving the door open or keeping the floor clean and dry – rules and regulations that are less effective. However, a door can only be left open if it has been designed so that it does not impede egress or block other common functions of care, and maintaining a clean and dry floor can be accomplished more easily if there is protection from the weather and cleaning supplies are located in convenient and accessible locations. Interventions need be considered in the context of additional interactions and functions. As an example, where ambient conditions might be mediated through design (e.g., selection of materials, inclusion of low-level night lighting), they may also be affected by day-to-day operations (e.g., policies and systems used for paging, integrated alarm alert systems, unobstructed lighting). An integrated design that considers the complexities of falls requires an understanding of the policies and procedures to be supported, as well as a model of care that defines workflow and related tasks.

Hignett (2013) offered a model that described system elements relative to stability. Building design, as the least frequently changing component, was therefore represented at the core of a falls management system that considers the patient/resident as an active (though transient) member of the risk management endeavor. However, there are varying levels of permanence within the built environment, and some decisions are more long-lasting than others. Furniture can be moved and flooring can be replaced as part of life-cycle maintenance, but spatial organization related to room and unit layout can be a bigger challenge if changes are needed to structural and service components (e.g., plumbing).

Stewart Brand (1995) described building as being adaptable - composed of layers of longevity in the built components. Brand categorized “shearing layers” according to varying rates of change (Table 4). In the synthesis of physical environment interventions, shearing layers were identified based upon the building design characteristic/design feature and an estimated asset life (American Hospital Association, 2013). In this manner, furniture (a "set/stuff" item that may change location frequently), becomes a "services" item, as the design factor related to the conceptual framework of stability is the life-cycle replacement consideration. [INSERT TABLE 4]

The result of organizing the physical environment interventions according to human factors/ergonomics environment categories and shearing layers is a recognition that **safety is a result of complexity of the organization, people, and environment (SCOPE) with building design at the core** (Figure 7). This notion expands Hignett's (2013) prior model of stability by adding detail for built environment classification, levels of permanence within the built environment, and the many interventions that have been tested or used as part of a multifactorial bundle. The simultaneous visualization of considerations can generate discussions surrounding the complexity and potential interactions of solutions. In this framework, longer life-cycle considerations in the design to mitigate fall risk are paramount. [INSERT FIGURE 7]

Beyond the environmental considerations, several studies referenced patients' over-estimation of their abilities. However, patients are rarely included in the review of safety events to provide their perspectives, even though patients may be the only "witness" to the event (Millman, Pronovost, Makary, & Wu, 2011). For example, recent studies found that patients often believe that intended solutions were appropriate for "other people" without recognizing the importance of their own participation in prevention activities (Haines, Day, Hill, Clemson, & Finch; Wolf & Hignett, 2015). Design teams should solicit and evaluate this input.

Two of the top three referenced interventions, risk assessments and alarms, may also be controversial in more recent thinking. As of June 2013, assessments are no longer a universal standard for accreditation in the UK (NICE, 2013), replaced by a suggested multifactorial assessment and customized set of interventions for anyone 65 years or older or for those 50-64 identified with an underlying condition of risk. Alarms are also under increasing scrutiny due to cognitive overload of caregivers and alarm fatigue. A sentinel event alert offers recommendations to reduce patient harm related to alarms (The Joint Commission, 2013). Alarms should be avoided if other solutions can be used.

Limitations

There were several limitations to this review. This review did not use two independent reviewers to conduct study selection, quality appraisal, and data extraction, but rather one worked under the guidance of a doctoral advisor. A single outcome defined for the review (e.g. fall reduction) to create a more inclusive search that would provide insight on the interventions being used and/or tested. There is often a lengthy period of time required in order to report significant change or maintenance of results, and this certainly raises some question for small sample sizes and short durations, even in the best designed study. For example, Drahota et al. (2013) estimated that to achieve the same results with 80% power would take 33,480–52,840 patient days per arm, 8–12 clusters, 1,800–2,700 participants per arm, and a two-year follow-up. Of the studies included in the review, few were empirical studies of individual fall prevention interventions, and studies of single interventions may best be considered in the context of a larger defined bundle, as with Barker et al. (2013). The studies were selected based on a primary goal of identifying latent conditions contributing to falls in healthcare facilities. Other studies that focused specifically on the referenced interventions (e.g., staffing, rounding, intrinsic conditions) were not included. However, this was by design, and the selected studies were intended to provide a holistic view of the complexity of hospital falls. Additionally, a systematic literature review is established through defined inclusion and exclusion criteria that includes the predefinition of search terms and combinations of terms for searches in scholarly databases. This is to reduce bias in study selection. While every effort was made to ensure a comprehensive search, some sources may not have been found through the keywords used in the systematic review. A particular challenge is inconsistent or non-standard terminology used as author-identified keywords, or inclusion of interventions and outcomes that were a secondary focus of the research topic in the study abstract.

Conclusions

While fall prevention is inextricably linked to the organization, people, and the physical environment, the built environment is often an undefined factor of stability. The primary aim of this falls literature review was to explore and appraise aspects of the built environment that would allow facility designers and related project teams to take a proactive approach to understand conditions that can contribute to the risk of falls. A secondary aim was to identify factors beyond the built environment that contribute to a systems approach. An aging hospital infrastructure necessitates that healthcare facilities continue to be built and renovated, and the underlying permanence of the physical environment should inform decisions to mitigate fall risks. Design teams can participate a falls management program by understanding comprehensive multifactorial approaches with the resulting decisions supporting the people that will occupy the facility, as well as organizational policies and procedures that influence how a facility will be operationalized.

References

ADA Standards for Accessible Design, 28 C.F.R. § 36.607 (2010).

American Hospital Association. (2013). *Estimated Useful Lives of Depreciable Hospital Assets* (Revised 2013 ed.). Chicago: AHA Press.

Barker, A., Kamar, J., Tyndall, T., & Hill, K. (2013). Reducing serious fall-related injuries in acute hospitals: are low-low beds a critical success factor? *Journal of Advanced Nursing, 69*(1), 112-121. doi:10.1111/j.1365-2648.2012.05997.x

Bell, J. L., Collins, J. W., Wolf, L., Gronqvist, R., Chiou, S., Chang, W. R., . . . Evanoff, B. (2008). Evaluation of a comprehensive slip, trip and fall prevention programme for hospital employees. *Ergonomics, 51*(12), 1906-1925. doi: 10.1080/00140130802248092

Bouldin, E. L., Andresen, E. M., Dunton, N. E., Simon, M., Waters, T. M., Liu, M., . . . Shorr, R. I. (2013). Falls among adult patients hospitalized in the United States: prevalence and trends. *Journal of Patient Safety, 9*(1), 13-17. doi:10.1097/PTS.0b013e3182699b64

Brand, S. (1995). *How buildings learn: What happens after they're built*. Retrieved from http://www.amazon.com/How-Buildings-Learn-Happens-Theyre/dp/0140139966#reader_B00AFZ3PI4.

Brandis, S. (1999). A collaborative occupational therapy and nursing approach to falls prevention in hospital inpatients. *Journal of Quality in Clinical Practice, 19*(4), 215-220.

Calkins, M. P., Biddle, S., & Biesan, O. (2012). *Contribution of the designed environment to fall risk in hospitals*. Retrieved from The Center for Health Design: https://www.healthdesign.org/sites/default/files/fall_risks_report_final.pdf

Carayon, P. (2011). *Handbook of human factors and ergonomics in health care and patient safety* (2nd ed.). Boca Raton, FL: CRC Press.

Carayon, P., Alvarado, C. J., & Hundt, A. S. (2007). Work design and patient safety. *Theoretical Issues in Ergonomics Science, 8*(5), 395-428. doi: 10.1080/14639220701193157

Choi, Y.-S., Lawler, E., Boenecke, C. A., Ponatoski, E. R., & Zimring, C. M. (2011). Developing a multi-systemic fall prevention model, incorporating the physical environment, the care process and technology: A systematic review. *Journal of Advanced Nursing, 67*(12), 2501-2524. doi:10.1111/j.1365-2648.2011.05672.x

Cigolle, C. T., Ha, J., Min, L. C., Lee, P. G., Gure, T. R., Alexander, N. B., & Blaum, C. S. (2015). The epidemiologic data on falls, 1998-2010: More older Americans report falling. *JAMA Internal Medicine, 175*(3), 443-445. doi:10.1001/jamainternmed.2014.7533

CMS Final Changes to the Hospital Inpatient Prospective Payment Systems and Fiscal Year 2009 Rates, CMS-1390-F C.F.R. § F. Preventable Hospital-Acquired Conditions (HACs), Including Infections (2008).

CMS Hospital Inpatient Prospective Payment Systems for Acute Care Hospitals and the Long‑Term Care Hospital Prospective Payment System and Fiscal Year 2014 Rates, CMS-1599-F C.F.R. § F. Adjustment to MS–DRGs for Preventable Hospital-Acquired Conditions (HACs), Including Infections (2013).

Cozart, H. C. T. (2009). Environmental effects on incidence of falls in the hospitalized elderly. (Doctoral dissertation), Texas Woman's University. ProQuest Dissertations & Theses (PQDT) database. (3399044).

Dacenko-Grawe, L., & Holm, K. (2008). Evidence-based practice: A falls prevention program that continues to work. *MEDSURG Nursing, 17*(4), 223-227.

Donald, I. P., Pitt, K., Armstrong, E., & Shuttleworth, H. (2000). Preventing falls on an elderly care rehabilitation ward. *Clinical Rehabilitation, 14*(2), 178-185.

Donaldson, L. J., Panesar, S. S., & Darzi, A. (2014). Patient-safety-related hospital deaths in England: Thematic analysis of incidents reported to a national database, 2010-2012. *PLoS Medicine, 11*(6). doi:10.1371/journal.pmed.1001667

Drahota, A. K., Ward, D., Udell, J. E., Soilemezi, D., Ogollah, R., Higgins, B., . . . Severs, M. (2013). Pilot cluster randomised controlled trial of flooring to reduce injuries from falls in wards for older people. *Age and Ageing, 42* (5), 633-640. doi:10.1093/ageing/aft067

Dykes, P. C., Carroll, D. L., Hurley, A. C., Benoit, A., & Middleton, B. (2009). Why do patients in acute care hospitals fall? Can falls be prevented? *The Journal of Nursing Administration, 39*(6), 299-304. doi:10.1097/NNA.0b013e3181a7788a

Fonda, D., Cook, J., Sandler, V., & Bailey, M. (2006). Sustained reduction in serious fall-related injuries in older people in hospital. *Medical Journal of Australia, 184*(8), 379-382. doi:fon10417_fm [pii]

Goodlett, D., Robinson, C., Carson, P., & Landry, L. (2009). Focusing on video surveillance to reduce falls. *Nursing, 39*(2), 20-21. doi:10.1097/01.NURSE.0000345233.09590.79

Gowdy, M., & Godfrey, S. (2003). Using tools to assess and prevent inpatient falls. *The Joint Commission Journal on Quality and Patient Safety, 29*(7), 363-368.

Gulwadi, G., & Calkins, M. (2008). *The Impact of Healthcare Environmental Design of Patient Falls*. Retrieved from The Center for Health Design: https://www.healthdesign.org/sites/default/files/impact_of_healthcare_environment_design_on_patient_falls.pdf

Gutierrez, F., & Smith, K. (2008). Reducing falls in a Definitive Observation Unit: an evidence-based practice institute consortium project. *Crit Care Nurs Q, 31*(2), 127-139. doi:10.1097/01.CNQ.0000314473.72001.b4

Haines, T. P., Day, L., Hill, K. D., Clemson, L., & Finch, C. (2014). "Better for others than for me": A belief that should shape our efforts to promote participation in falls prevention strategies. *Archives of Gerontology and Geriatrics, 59*(1), 136-144. doi:10.1016/j.archger.2014.03.003

He, J., Dunton, N., & Staggs, V. (2012). Unit-level Time Trends in Inpatient Fall Rates of U.S. Hospitals. *Medical Care, 50*(9), 801-807.

Healey, F. (1994). Does flooring type affect risk of injury in older in-patients? *Nurs Times, 90*(27), 40-41.

Hendrich, A. (2006). Inpatient falls: Lessons from the field. *Patient Safety and Quality Healthcare*(May-June). Retrieved from http://psqh.com/inpatient-falls-lessons-from-the-field

Hignett, S. (2013). Why design starts with people. *The Health Foundation*, 1-5.

Henriksen, K. (2011). Opportunities and Challenges in the Pursuit of Patient Safety. In P. Carayon (Ed.), *Handbook of Human Factors and Ergonomics in Health Care and Patient Safety* (2nd ed., pp. 17-26). Boca Raton, FL: CRC Press.

Hitcho, E. B., Krauss, M. J., Birge, S., Claiborne Dunagan, W., Fischer, I., Johnson, S., . . . Fraser, V. J. (2004). Characteristics and circumstances of falls in a hospital setting: a prospective analysis. *J Gen Intern Med, 19*(7), 732-739. doi:10.1111/j.1525-1497.2004.30387.x JGI30387 [pii]

Institute for Safe Medication Practices. (1999). Medication error prevention "toolbox". *ISMP Medication Safety Alert! Acute Care.* Retrieved from http://www.ismp.org/newsletters/acutecare/articles/19990602.asp

Institute of Medicine (IOM). (1999). *To err is human: Building a safer health system*. Washington, DC: National Academy Press.

Institute of Medicine (IOM). (2001). *Crossing the quality chasm: A new health system for the 21st century*. Washington, DC: National Academy Press.

Jorgensen, T. S., Hansen, A. H., Sahlberg, M., Gislason, G. H., Torp-Pedersen, C., Andersson, C., & Holm, E. (2015). Nationwide time trends and risk factors for in-hospital falls-related major injuries. *International Journal of Clinical Practice, 69*(6), 703-709. doi:10.1111/ijcp.12624

Kandel, J., & Adamec, C. A. (2009). *The Encyclopedia of Elder Care*. New York, NY: Facts on File.

Karwowski, W. (2012). The Discipline of Human Factors and Ergonomics. In G. Salvendy (Ed.), *Handbook of human factors and ergonomics* (4th ed.). Hoboken, NJ: Wiley.

Krauss, M. J., Tutlam, N., Costantinou, E., Johnson, S., Jackson, D., & Fraser, V. J. (2008). Intervention to prevent falls on the medical service in a teaching hospital. *Infection Control and Hospital Epidemiology, 29*(6), 539-545. doi:10.1086/588222

Liberty Mutual Research Institute for Safety. (n.d.). Manual Materials Handling Guidelines. Liberty Mutual Insurance Company. Retrieved from https://libertymmhtables.libertymutual.com/CM_LMTablesWeb/pdf/LibertyMutualTables.pdf

Lopez, K. D., Gerling, G. J., Cary, M. P., & Kanak, M. F. (2010). Cognitive work analysis to evaluate the problem of patient falls in an inpatient setting. *Journal of the American Medical Informatics Association, 17*(3), 313-321. doi:10.1136/jamia.2009.000422

Mays, N., Pope, C., & Popay, J. (2005). Systematically reviewing qualitative and quantitative evidence to inform management and policy-making in the health field. *Journal of Health Services Research & Policy, 10* (Suppl 1), 6-20. doi:10.1258/1355819054308576

Millman, E. A., Pronovost, P. J., Makary, M. A., & Wu, A. W. (2011). Patient-assisted incident reporting: Including the patient in patient safety. *Journal of Patient Safety, 7*(2), 106-108.

Mosley, A., Galindo-Ciocon, D., Peak, N., & West, M. J. (1998). Initiation and evaluation of a research-based fall prevention program. *Journal of Nursing Care Quality, 13*(2), 38-44.

National Institute for Health and Care Excellence (NICE). (2013). *Falls: Assessment and prevention of falls in older people, NICE Guidelines [CG 161] NICE guidelines* (pp. 31). Retrieved from guidance.nice.org.uk/cg161.

National Patient Safety Agency (NPSA). (2010). *Slips trips and falls data update* (1259). Retrieved from http://www.nrls.npsa.nhs.uk/resources/?EntryId45=74567

Occupational Safety & Health Administration. (2015). OSHA adds key hazards for investigators' focus in healthcare inspections [Press release]. Retrieved from https://www.osha.gov/newsrelease/nat-20150625.html

Ohde, S., Terai, M., Oizumi, A., Takahashi, O., Deshpande, G. A., Takekata, M., . . . Fukui, T. (2012). The effectiveness of a multidisciplinary QI activity for accidental fall prevention: Staff compliance is critical. *BMC Health Services Research, 12*, 197. doi:10.1186/1472-6963-12-197

Popay, J., Roberts, H., Sowden, A., Petticrew, M., Arai, L., Rodgers, M., . . . Duffy, S. (2006). *Guidance on the conduct of narrative synthesis in systematic reviews*. Retrieved from http://www.lancaster.ac.uk/shm/research/nssr/research/dissemination/publications.php

QSR International. (2012). NVivo qualitative data analysis software (Version 10): QSR International Pty Ltd. Retrieved from http://www.qsrinternational.com

Schaffer, P. L., Daraiseh, N. M., Daum, L., Mendez, E., Lin, L., & Huth, M. M. (2012). Pediatric inpatient falls and injuries: a descriptive analysis of risk factors. *Journal for Specialists in Pediatric Nursing, 17*(1), 10-18. doi:10.1111/j.1744-6155.2011.00315.x

Shorr, R. I., Chandler, A. M., Mion, L. C., Waters, T. M., Liu, M., Daniels, M. J., . . . Miller, S. T. (2012). Effects of an intervention to increase bed alarm use to prevent falls in hospitalized patients: A cluster randomized trial. *Annals of Internal Medicine, 157*(10), 692-699. doi:10.7326/0003-4819-157-10-201211200-00005

Staggs, V. S., Mion, L. C., & Shorr, R. I. (2014). Assisted and unassisted falls: Different events, different outcomes, different implications for quality of hospital care. *The Joint Commission Journal on Quality and Patient Safety, 40*(8), 358-364.

Taylor, E., & Hignett, S. (2014). Evaluating Evidence: Defining Levels and Quality through Existing Methods. *HERD: Health Environments Research & Design Journal, 7*(3), 144-151. doi:10.1177/193758671400700310

The Joint Commission. (2013). Sentinel event alert issue 50: Medical device alarm safety in hospitals. *Sentinel Event Alert,* (50), 1-3. Retrieved from http://www.jointcommission.org/assets/1/18/SEA_50_alarms_4_5_13_FINAL1.PDF

The Joint Commission. (2015). Sentinel event alert 55: Preventing falls and fall-related injuries in health care facilities. *Sentinel Event Alert,* (55), 1-5. Retrieved from http://www.jointcommission.org/assets/1/18/SEA_55.pdf

The Joint Commission. (2016, February 9). Sentinel Event Statistics Data - Root Causes by Event Type (2004 - 2015) *Sentinel event data - root causes by event type.* Retrieved from http://www.jointcommission.org/assets/1/18/Root_Causes_by_Event_Type_2004-2015.pdf

Tzeng, H. M. (2011). Triangulating the extrinsic risk factors for inpatient falls from the fall incident reports and nurse's and patient's perspectives. *Applied Nursing Research, 24*(3), 161-170. doi:10.1016/j.apnr.2009.06.005

Tzeng, H. M., & Yin, C. Y. (2008). The extrinsic risk factors for inpatient falls in hospital patient rooms. *Journal of Nursing Care Quality, 23*(3), 233-241. doi:10.1097/01.NCQ.0000324588.91837.84 00001786-200807000-00010 [pii]

U.S. Department of Health & Human Services. (2014). *New HHS data shows major strides made in patient safety, leading to improved care and savings*. Retrieved from The Center for Medicare & Medicaid Innovation (the Innovation Center): http://innovation.cms.gov/Files/reports/patient-safety-results.pdf

Vassallo, M., Azeem, T., Pirwani, M. F., Sharma, J. C., & Allen, S. C. (2000). An epidemiological study of falls on integrated general medical wards. *International Journal of Clinical Practice, 54*(10), 654-657.

Vieira, E. R., Berean, C., Paches, D., Costa, L., Decombas-Deschamps, N., Caveny, P., . . . Ballash, L. (2011). Risks and suggestions to prevent falls in geriatric rehabilitation: a participatory approach. *BMJ Quality & Safety, 20*(5), 440-448. doi:10.1136/bmjqs.2010.042382

Warren, C. J., & Hanger, H. C. (2013). Fall and fracture rates following a change from carpet to vinyl floor coverings in a geriatric rehabilitation hospital. A longitudinal, observational study. *Clinical Rehabilitation, 27*(3), 258-263. doi:10.1177/0269215512455530

Wayland, L., Holt, L., Sewell, S., Bird, J., & Edelman, L. (2010). Reducing the patient fall rate in a rural health system. *Journal for Healthcare Quality, 32*(2), 9-14; quiz 14-15.

Wilson, J. R., & Corlett, N. (2005). *Evaluation of human work* (3rd ed.). Boca Raton, FL: CRC Press.

Wolf, L., Costantinou, E., Limbaugh, C., Rensing, K., Gabbart, P., & Matt, P. (2013). Fall prevention for inpatient oncology using lean and rapid improvement event techniques. *HERD: Health Environments Research & Design Journal, 7*(1), 85-101.

Wolf, L., & Hignett, S. (2015, August). *Are patients at risk of falling? Not if you ask them!* Paper presented at the 19th Triennial Congress of the International Ergonomics Association (IEA 2015), Melbourne, Australia.

Summary

Fall prevention as a safety issue is complex and is inextricably linked to the organization, people and the physical environment. Building design is often an undefined factor of stability and permanence that can inform decisions to mitigate fall risks in both new construction and renovation. However, multifactorial (bundled) approaches make it difficult to quantify the effect of any particular intervention when preventing hospital falls. With this complexity in mind, a systematic mixed studies review was conducted to understand the range of conditions associated with falls risk. The primary aim of this review was to explore and appraise aspects of the built environment to allow facility designers and related project teams to take a proactive approach to understand conditions contributing to the risk of falls. A secondary aim was to identify factors beyond the built environment that contribute to a systems approach to this persistent problem. It is clear from the number, prevalence, and quality appraisal of interventions that there is no single or obvious prescriptive solution. Decisions needs to consider interactions and address the people that will occupy the facility, as well as organizational policies and procedures that influence how a facility will be operationalized.

Implication for Practice

- Hospital falls are complex and design teams can support a falls management program by understanding comprehensive multifactorial approaches that include building design.
- Using a systems approach of human factors/ergonomics (HF/E), the results of the systematic review are broadly categorized as the organization (operations, policies and procedures), people (staff and patients), and the environment (facility design).
- A dual matrix appraisal system visually portrays the level and methodological quality of evidence for interventions to mitigate fall risk is used for organizational, people and environment factors
- Facility design interventions to mitigate the risk of falls can also be characterized by physical environment categories, design features, and the permanence defined by estimated asset life.
- The simultaneous visualization of multifactorial considerations can generate discussions surrounding the complexity and potential interactions of solutions that consider a systems approach to falls prevention management.

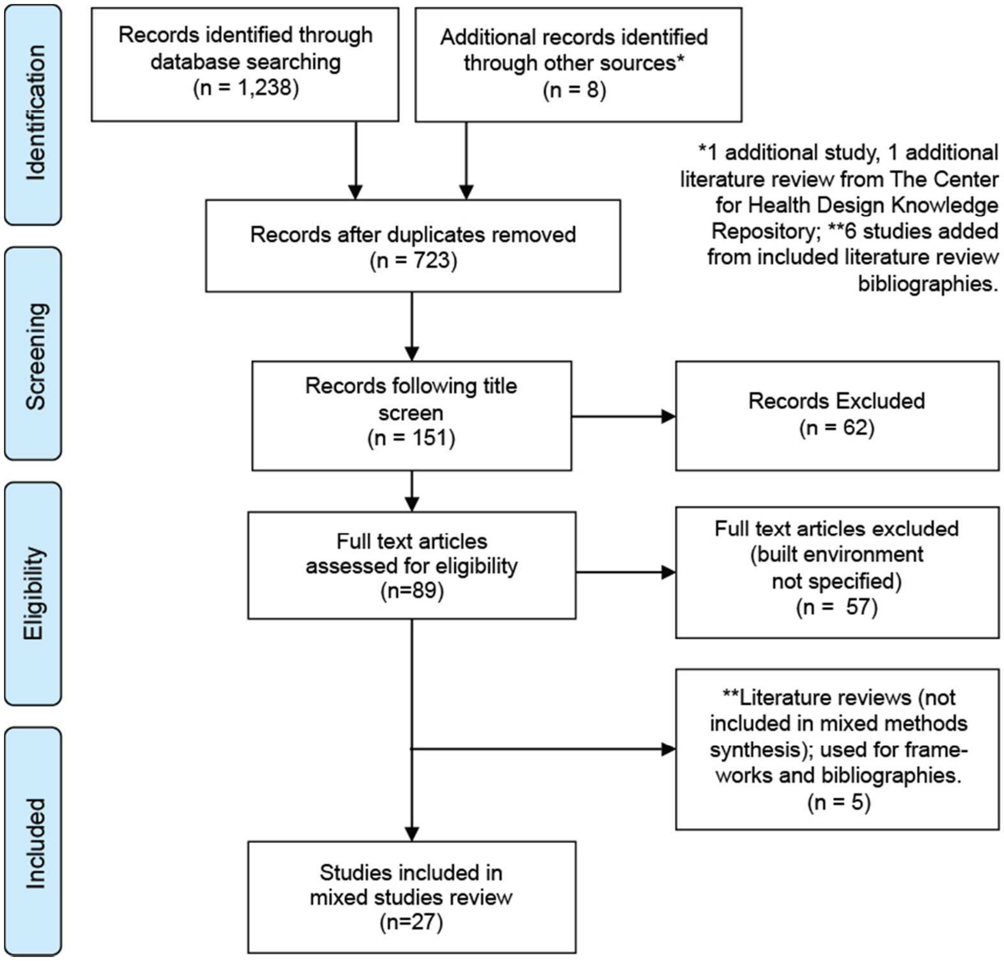

Figure 1: Search Strategy and Inclusion Flow

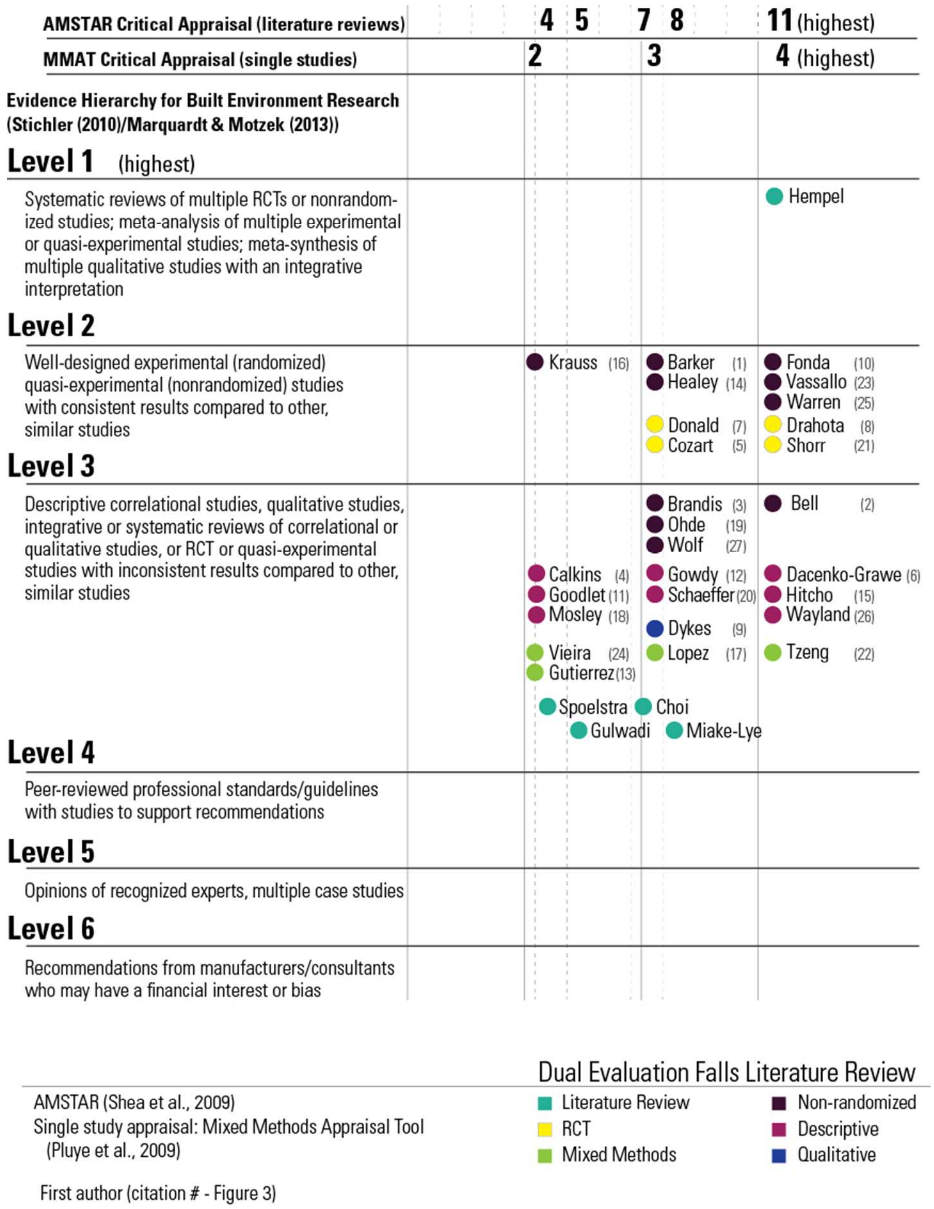

Figure 2: Evidence Categorization and Appraisal Matrix for Hospital Falls Review

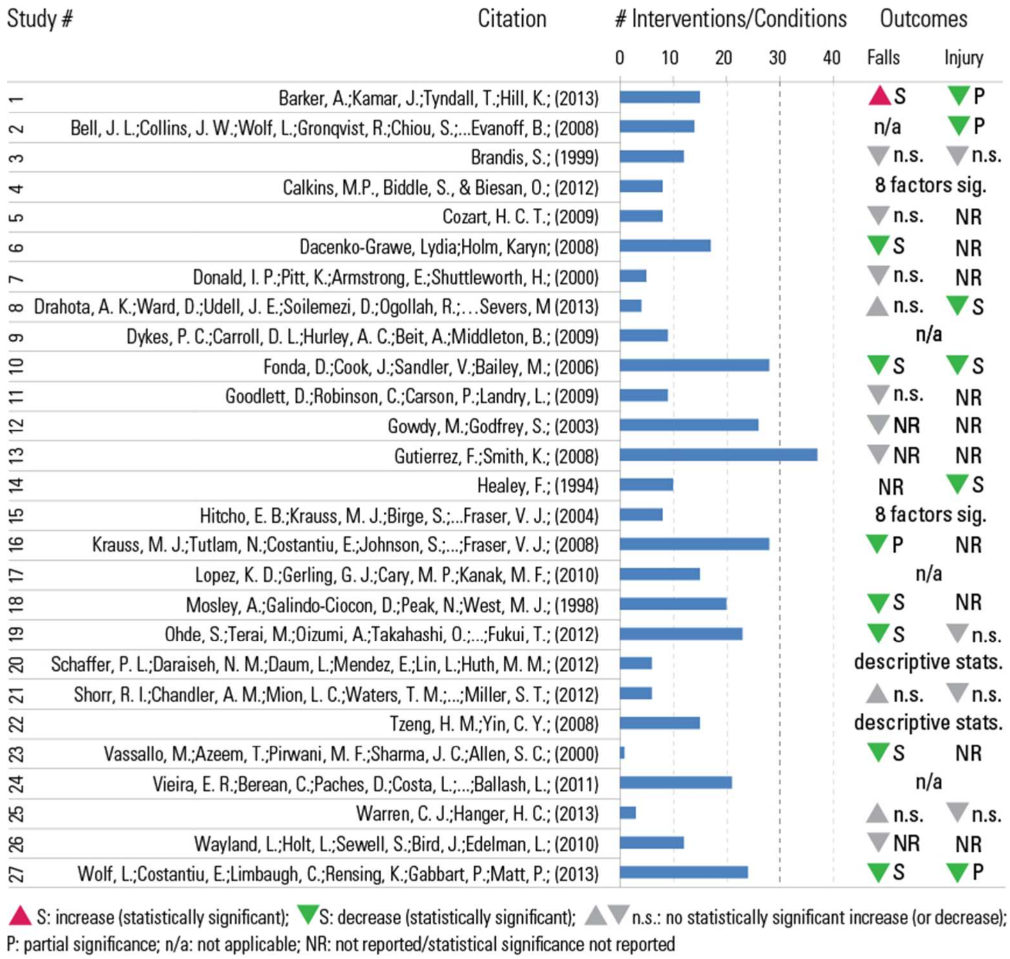

Figure 3: Study citation abbreviation, study ID, interventions and outcomes

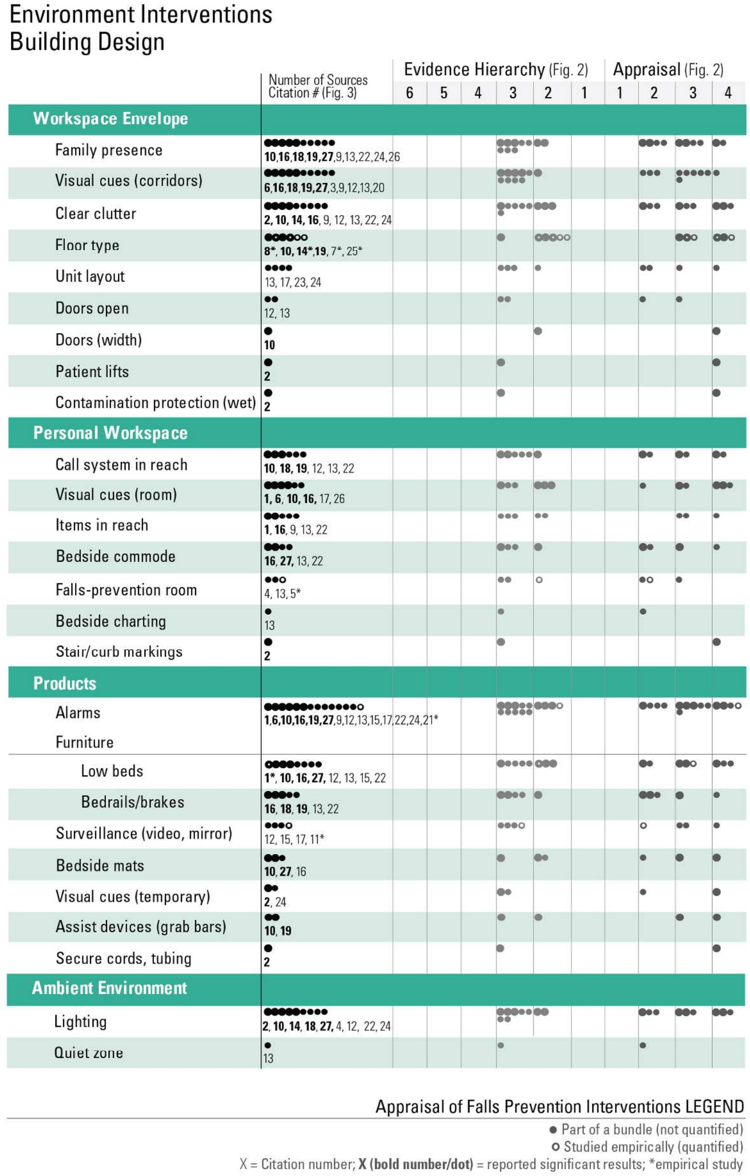

Figure 4: Physical Environment Interventions to Mitigate Falls
152x234mm (300 x 300 DPI)

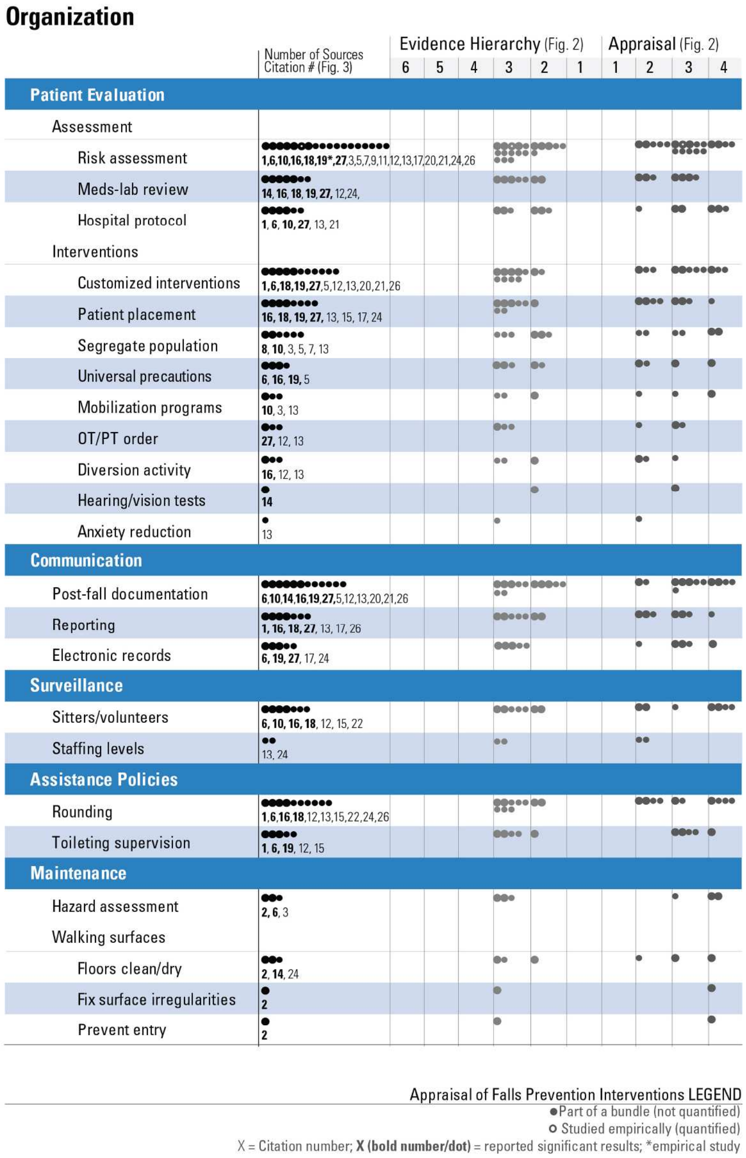

Figure 5: Organizational Interventions to Mitigate Falls Risk
152x234mm (300 x 300 DPI)

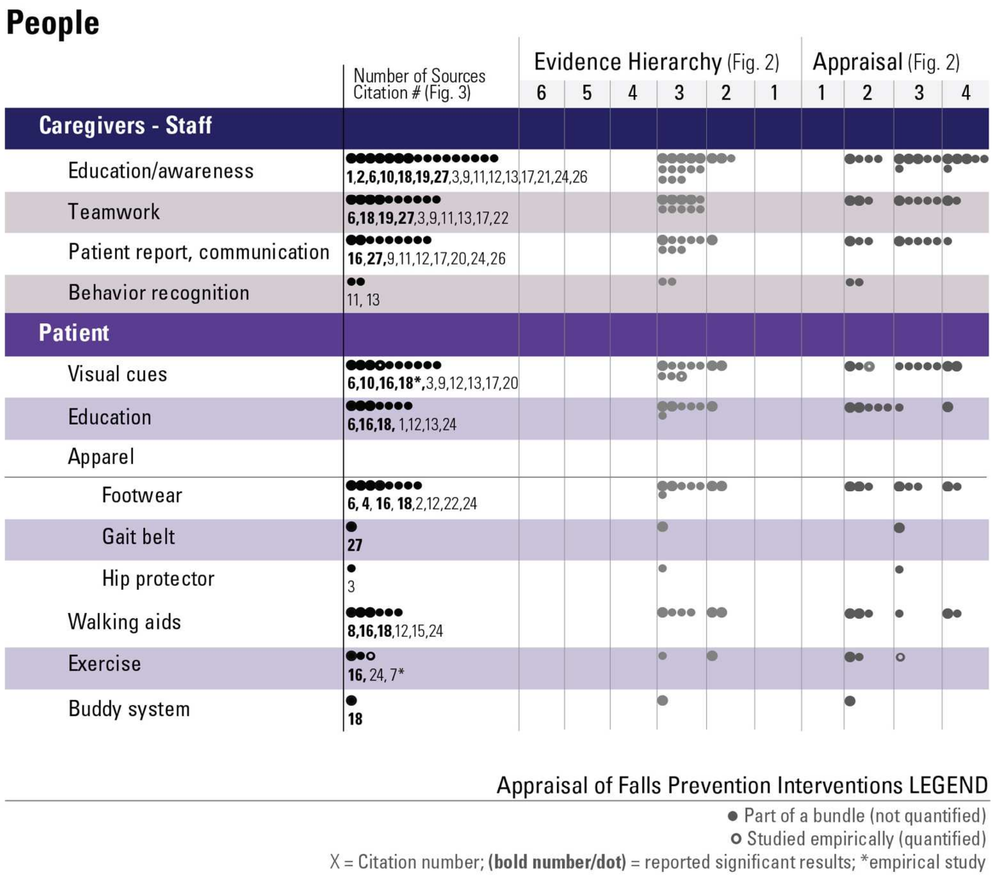

Figure 6: People-based Interventions to Mitigate Falls Risk
146x129mm (300 x 300 DPI)

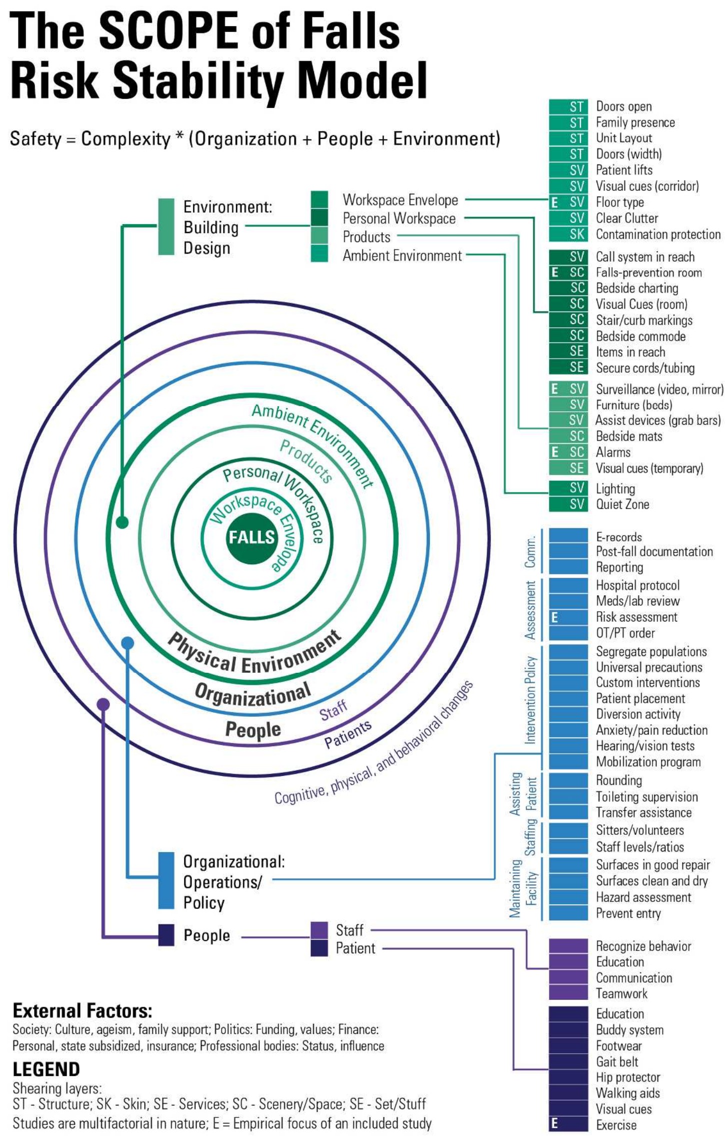

Figure 7: The SCOPE model for falls
152x248mm (300 x 300 DPI)

Table 1

Sample searches for hospital falls systematic review

Search Number	*Terms Used*
1	falls AND intervention AND hospital AND environment
2	"Interior Design and Furnishings" or floor* OR "equipment design" or bed* or toilet* AND ("Patient safety" or "safety management" or "safety culture") AND "risk factor*" or "risk assessment" or "risk management" AND ("Built Environment" or "Physical environment" or "Health Facility Environment" or "Environment Design" or Hospital) AND (prevention or intervention*) AND fall* NOT (resident Or home OR community) NOT "nursing home"
3	("Patient safety" or "safety management" or "safety culture") AND "risk factor*" or "risk assessment" or "risk management" AND ("Built Environment" or "Physical environment" or "Health Facility Environment" or "Environment Design" or Hospital) AND (prevention or intervention*) AND fall* NOT (resident Or home OR community) NOT "nursing home"

Table 2

Extrinsic Correlates of Hospital Falls (Environment)

Category	*Extrinsic Conditions*	*Citations*
Environment: Workspace Envelope	Unit layout (visibility)	(Brandis, 1999; Calkins, 2012; Goodlett et al., 2009; Hitcho et al., 2004; Vassallo et al., 2000; Wolf et al., 2013)
	Clutter (tripping hazards)	(Bell et al., 2008; Hitcho et al., 2004; Mosley et al., 1998; Tzeng & Yin, 2008; Vieira et al., 2011; Wolf et al., 2013)
	Bathroom location or distance to bathroom	(Brandis, 1999; Calkins, 2012; Krauss et al., 2008; Tzeng & Yin, 2008; Wolf et al., 2013)
	Flooring (Floor type as a factor (generically); more falls on linoleum as compared to other surfaces; floor transitions (thickness change)	(Calkins, 2012; Drahota et al., 2013; Fonda et al., 2006; Lopez et al., 2010; Ohde et al., 2012; Schaffer et al., 2012)
	Lack of space for family within the room	(Calkins, 2012)
	Doors in patient rooms not open/out of the way (due to spatial conflicts)	(Calkins, 2012)
	No patient lifts	(Calkins, 2012)
	Shared rooms and bathrooms/no bathrooms	(Calkins, 2012)
	Floor color and patterns	(Calkins, 2012; Fonda et al., 2006)
	Level change (stairs, curbs)	(Bell et al., 2008)
	Cords and tubing	(Tzeng & Yin, 2008)
Environment: Personal Workspace	Bathroom layout (i.e., sidewall toilet versus directly across from the entry)	(Calkins, 2012)
	Call system inaccessibility	(Mosley et al., 1998)
	Bedside commodes	(Hitcho et al., 2004)
	Lack of/poorly positioned permanent assistive devices (e.g., grab bars)	(Brandis, 1999; Calkins, 2012; Lopez et al., 2010; Mosley et al., 1998)
Environment: Products	Furniture (generic)	(Fonda et al., 2006)
	Bedrails (i.e., used as restraint)	(Brandis, 1999; Hitcho et al., 2004; Mosley et al., 1998; Tzeng & Yin, 2008)
	Unstable/unmovable furniture	(Bell et al., 2008; Vieira et al., 2011);
	Inability to put beds in low positions	(Brandis, 1999; Tzeng & Yin, 2008; Wolf et al., 2013)
	Bed/chair alarms – movement alert (i.e., unavailable, inaudible, deactivated, irregularly used)	(Lopez et al., 2010; Tzeng & Yin, 2008; Vieira et al., 2011; Wolf et al., 2013)
Environment: Ambient Environment	Poor lighting (i.e., toileting at night)	(Fonda et al., 2006; Lopez et al., 2010; Mosley et al., 1998; Tzeng & Yin, 2008; Vieira et al., 2011; Wolf et al., 2013)
	Noise (e.g., alarms, overahead paging that hampers sleep)	(Calkins, 2012)

Table 3

Extrinsic Correlates of Hospital Falls (Organization and People)

Category	*Extrinsic Conditions*	*Citations*
Organization	Staffing:	
	Patients left unattended	(Tzeng & Yin, 2008)
	Higher staffing levels correlated to more falls	(Brandis, 1999; Krauss et al., 2008)
	Turnover (staff/leadership)	(Wolf et al., 2013)
	Maintenance: Contamination of surfaces – ice, rain, urine	(Bell et al., 2008; Brandis, 1999; Healey, 1994; Hitcho et al., 2004; Mosley et al., 1998; Tzeng & Yin, 2008; Vieira et al., 2011; Wolf et al., 2013).
	Waxed floors	(Bell et al., 2008)
People: Patients	Footwear	(Fonda et al., 2006; Mosley et al., 1998; Schaffer et al., 2012; Tzeng & Yin, 2008; Vieira et al., 2011; Wolf et al., 2013)
	Medications	(Schaffer et al., 2012; Tzeng & Yin, 2008; Vieira et al., 2011; Wolf et al., 2013)
	No walking aids	(Mosley et al., 1998; Tzeng & Yin, 2008; Vieira et al., 2011)
	Lack of familiarity with the space	(Mosley et al., 1998; Vassallo et al., 2000; Wayland et al., 2010)
	Transfer movements (e.g., bed to chair)	(Cozart, 2009; Mosley et al., 1998; Tzeng & Yin, 2008)
People: Staff	Communication breakdowns	(Dykes et al., 2009; Gowdy & Godfrey, 2003; Gutierrez & Smith, 2008; Lopez et al., 2010; Tzeng & Yin, 2008)
	Cognitive overload/workload	(Lopez et al., 2010; Tzeng & Yin, 2008; Wolf et al., 2013)
	Reflex injuries during patient assistance that preclude the fall prevention underway	(Fonda et al., 2006)

Table 4

Shearing layers (adapted from Brand [1995])		
Shearing layer	*Life*	*Descriptions*
Site	Eternal	Geographical setting, the urban/suburban location, legally defined lot
Structure (ST)	30-60 years	The foundation and load-bearing elements; rarely change due to expense/difficulty
Skin (SK)	20 years	Exterior surfaces may change for aesthetics or state of good repair
Services (SE)	7-15 years	Internal workings that wear out or become obsolete: communications wiring, electrical wiring, plumbing, fire sprinkler systems, HVAC and moving pats (e.g., elevators, escalators)
Scenery/Space (SC)	3+ years	Interior layout of walls, ceilings, floors, and doors
Set/Stuff (SE)	Daily to monthly	Furniture and components that move regularly