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Research Approaches to the Prevention and Protection of Patient Falls

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Since the 1970s, patient falls and, in particular, patient injuries from falls have been a concern to acute-care hospitals, rehabilitation centers, and long-term care institutions. It is estimated that annually "somewhere between 700,000 and 1,000,000 people in the United States fall in hospitals" (Ganz et al., 2013, p. 1). Approximately 5.1%* experienced a major injury; 137,255–196,078 patients per year received a major injury, such as a fracture or major head injury.

In the last five decades, the practice and research approaches to the problem of preventing patients from falling have changed dramatically. Falls were first considered a normal consequence of aging, a random event, or an unavoidable accident. But today, patient falls are considered both predictable and preventable. Despite various approaches to fall intervention and advances in technology, patient fall rates have not decreased significantly. Fall injuries have become the anathema of the health-care industry.

Here, in Sections 20.1 through 20.5, we describe and summarize the problem of patient falls. We examine the changes in fall interventions that have occurred over time and discuss the present approaches to fall intervention. In Sections 20.6 and 20.7, we discuss advances in biomedical and ergonomic approaches to fall intervention research and how they affect patient care. In particular, we present current biomechanical and ergonomic research to facilitate understanding patient ingress, egress, and in-bed movements as they contribute to fall potential, research approaches, and patient safety. We present slip/fall issues related to the design of bathrooms in Section 20.8 and a summary of the chapter in Section 20.9.

20.1 The Problem of Patient Falls

20.1.1 What Is a Patient Fall?

One of the difficulties in reporting and monitoring patient falls is that the commonly accepted definition of a *fall* is clinically inadequate: "the patient comes to rest unintentionally on the floor" (Morris and Isaacs, 1980). This definition causes confusion: Does it include a "saved" (intercepted) fall in which the patient is "caught" by a caregiver and lowered to the floor, and the risk of injury is reduced? Does it include falls when the patient does not "come to rest" on

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* Rate reported by Schwendiman et al. (2008).

the floor, for instance, falls into a chair or other object? If the patient slides down a wall to the floor, is a slide a fall? Does "falling" include falls from the commode or wheelchair or chair or if a patient rolls out of bed, or must the person be in a standing position?

To complicate matters further, fall records often contain extraneous instances: falls by staff members and visitors and when a patient (or even an infant) is *dropped* by caregivers. A *drop* is not a fall.

The severity of a fall injury is dependent on (1) the distance of the free fall (i.e., impact velocity), (2) the trajectory of the fall (i.e., the part of the body landing on the floor), and (3) the deceleration distance (cushioning of the fall). If an institution has a "no fall" policy, there is an underlying belief that falling itself is dangerous and must not occur at any cost. The institution supports fall *prevention strategies*—strategies to prevent falls, the ultimate of which is the use of restraints or an enclosed bed. Patients are reminded constantly not to fall, so "fear of falling" (Butcher, 2013; Zijlstra et al., 2007) may impede rehabilitation.

On the other hand, institutions that are tolerant of falls (often rehabilitation units or nursing homes that prioritize mobility and independence) take precautions to prevent injury—fall protection strategies. They emphasize passive prevention strategies and are particular about the position of handrails, for instance, and use hip protectors, vigilance, walking aids, and assistance. These institutions focus on the injury rate rather than the fall rate as indicators of success. Of course the nature of the patient population also "drives" the type of interventions (preventive or protective), because facilities with cognitively impaired patient populations must primarily use fall preventive interventions.

This focus on prevention versus protection begs an important question: Should institutions be primarily concerned about fall rate or injury rate? Fall rates reported by institutions are erratic and imprecise, subject to reporting error and misreporting. Compounding the problem of an unclear definition of fall, nurses are reluctant to report *all* falls. When a patient for whom they are responsible falls, it is often considered the result of "poor care" and their personal responsibility, regardless of the cause of the fall. The reporting process is perceived as punitive, and this may be compounded if the incident is followed by legal action, which is carried out against the institution but may also implicate individual staff members.

Falls within health-care institutions are usually reported as the number of falls per 1000 patient bed days (Morse and Morse, 1988). Fall rates vary according to the patient population, the age of the institution (with increased rates in older hospitals), restraint use, the availability of fall prevention strategies, and the quality of nursing care. In fact, fall rates are used as an indicator of the quality of care as a nurse-sensitive patient outcome (Cho et al., 2003). Patient factors, such as patient acuity and mental status and treatments, also affect the fall rate. National databases have been established so that institutions can monitor their rates and compare their institution's rates nationally with institutions of a similar size and patient population (Gajewski et al., 2007). Conversely, injury rates provide a much more accurate indication of "what is going on." Nevertheless, an injury is a much less common occurrence, and because of its link to "quality of care" and legal action, injury reports are released reluctantly by the institution. However, the bottom line is that, whether institutions are prevention or protection oriented, the goal of fall intervention programs is to prevent patient injury.

20.1.2 Types of Patient Falls

There are three types of falls as classified by the cause of the falls*: anticipated physiological falls, unanticipated physiological falls, and accidental falls.

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* We are excluding *developmental falls*, that is, toddlers falling in the process of learning to walk.

20.1.2.1 Anticipated Physiological Falls

Anticipated physiological falls are falls that occur in patients who have some type of impaired gait or cognitive impairment and/or a history of falling. These falls can be predicted by fall-risk triage scales, and they comprise 78%–82% of hospital falls (Morse, 2009). Anticipated physiological falls do not occur randomly but occur in fall-prone patient populations. The highest rates are among nursing-home residents, especially the frail elderly, with rates of approximately 3–13 falls per 1000 patient bed days (Oliver et al., 2007). Rehabilitation hospitals have falls rates ranging from 4 to 9/1000 patient bed days (Nyberg and Gustafson, 1997; Vassallo et al., 2004) and include some very high-risk groups, such as stroke patients (Macintosh et al., 2005). In acute-care hospitals, oncology patients are at high risk because of extreme weakness and fatigue, and medical centers have rates 3.6/1000 patient bed days (Donaldson et al., 2005).

20.1.2.2 Unanticipated Physiological Falls

Unanticipated physiological falls comprise 8% of all falls and occur in patients who otherwise have a normal fall score but experience an "event" (Morse, 2009). These patients may faint or have a drug reaction, a hypovolemic episode, a knee that "gives way," or a seizure. The first fall cannot be predicted and therefore cannot be prevented, but the patient should be protected from injury, lest the condition, and a second fall, occur.

20.1.2.3 Accidental Falls

Accidental falls occur in patients with normal gait and who have a normal fall score. The fall may be due to slipping or tripping (Morse et al., 1987; Morse, 2009), and prevention strategies are primarily enacted through ensuring a safe environment.

Does this mean that those who score at risk of falling do not fall accidentally? Those who score at risk of falling and have a shuffle, for instance, are more inclined to trip on a raised part of the floor; those with an impaired balance are more likely to slip, and those who are cognitively impaired are more likely to exit the bed without permission. They are an "accident about to happen." We expect these patients to fall and therefore put interventions in place to avoid conditions of an accidental fall. Importantly, we do not code these falls as accidents but as *unanticipated physiological falls*.

20.1.3 Consequences of Patient Falls

Injuries from falls are reported as minor, moderate, severe, or resulting in death (see List 20.1). Because these falls are from standing height or from the bed, the elderly, frail patient is more likely to be injured in a fall.

LIST 20.1

Classification of Injuries

Minor injuries (28% of falls) are bruises or abrasions, and there is usually no long-term consequence.

Moderate injuries (3%) consist of contusions, infiltrated IVs.

Serious injuries (0.01%–5.1%) are fractures, head injuries, burst wounds, or death. Death may result from a fractured skull or subdural hemorrhage or occur as a result of complications of a fractured hip and secondary to pneumonia, approximately 6 weeks after the fall (Donaldson et al., 2005).

As noted earlier, patient injury is generally the result of the trajectory of the fall, the height of the fall, the impact, the part of the body being impacted, and the deceleration distance. From standing height, patients may slip and fall backward, fracturing the occiput and/or causing a subdural hemorrhage; slip sideways and fracture a hip, or manage to "break" the fall with their hand and suffer a fractured wrist or arm; or impact their shoulder or chest, fracturing ribs, by falling against an obstacle. Falling forward, they may also fracture an arm or wrist or injure their face and fracture their nose. Abrasions are common, and frequently patients may dislodge and infiltrate an IV, dislodge drainage tubes or catheters, or rupture a surgical wound. Patients may hit their head on the furniture or other obstacles as they fall. They may fall by rolling out of bed, or by climbing over the side rails or the end of the bed and then falling onto the floor. Because a patient may incur several injuries in one incident, the most severe injury per fall is recorded.

20.1.3.1 Repeated Falls

Hospitals often consider a patient fall an independent event, yet repeated falls (patients who fall more than once) may quickly inflate the fall statistics. Of concern, 55% of patients who fall a second time were doing the same activity as in the first fall (Morse et al., 1985). Tracking patients who fall by activity and time of fall may assist in the identification of interventions and the prevention of falls.

20.1.4 Cost of Fall Injuries to the Health-Care System

Nationwide, the cost of moderate and serious injuries from falls has become so high that in 2008, Medicare stopped reimbursing hospitals for hospital-acquired conditions developed during the patient's stay, including injuries from hospital falls (Inouye et al., 2009). These nonreimbursable costs were estimated at between $4,000 (Inouyne et al., 2009) to $13,316 (Ganz et al., 2013) per fall. The injury costs of hospital falls are not covered by insurance; hospitals are responsible for the cost of care. Underlying this rationale is the value that patient falls are preventable and occur because of poor care practices.

Besides the financial cost, there is the cost to an individual of a fall injury, disability, and loss of independence. Even if a fall does not result in injury, psychological consequences, for example, the fear of falling (Zijlstra et al., 2007), often inhibits rehabilitation.

20.2 Historical Approaches to Fall Prevention

Over the past five decades, there have been shifts in patient acuity and length of stay, so that patients in the 2000s are much sicker than those in hospitals 20 years earlier. Along with this increasing acuity, the length of hospital stays has been reduced, so that patients are discharged earlier; the average length of stay (LOS) in acute-care institutions is now only 3.5 days. Recognizing the health risks of bed rest, patients are also mobilized more quickly and are often out of bed on the same day as surgery. Changes in rehabilitation include a reduced reliance on staff assistance and an increased emphasis on independence.

There have also been changes in the institution itself, with hospital design from the Nightingale wards (where all beds were in one large room, and patients could be easily surveyed by staff), to four-bed and two-bed wards, to a single room. This change resulted in increased patient privacy but made staff monitoring of the patients more difficult. Side rails, originally high and full length, became shorter, and they have been removed altogether from nursing-home beds. Hospitals introduced "sitters," that is, minimally trained staff, to observe patients. The removal of restraints resulted in the development of bed alarms, chair alarms, and alarms to alert staff if a patient climbed out of bed or door alarms if the patient wandered from the unit. Video surveillance is now being added to these technological advances for monitoring patients.

20.2.1 Changes in Fall Rates over Time

In the 1970s, hospitals began to track the number of falls and fall injuries, but the primary intervention made to prevent patient falls was the use of restraints; little else was available. Astonishingly, despite extraordinary efforts and fall prevention strategies that have become highly technical and have expanded over the decades, fall rates have remained relatively stable (or even increased) over the decades (see Table 20.1). This may be due to dramatic increases in patient acuity, with patients now being much sicker (and therefore weaker and more fall prone) than in previous decades. As mentioned, attitudes toward rehabilitation have changed, with the patients out of bed sooner (and therefore more fall prone); changes in fall reporting within the institution have also become more sensitive, and therefore fall rates are more accurate.

Patient fall rates and injury rates are used as a benchmark of the quality of care. The California Nursing Outcome Coalition (CalNOC) reported patient falls as a nurse-related quality indicator from 48,485 falls over 24 consecutive quarters (to March 2004); 74% occurred in medical–surgical units. (Gajewski et al., 2007).

Patient fall-injury rates often vary in different studies. In the CalNOC report, Gajewski et al. (2007) note that 32% sustained an injury (28% mild, 3.0% moderate, 1.0% major injury or death), and Schwendiman et al. (2006) report that 33.6% sustained an injury, 29.7% a minor injury, and 3.9% a major injury.

20.2.1.1 Hospital Beds and Falls

Adult hospital beds were originally built in one size, with a deck height of 36 in. Bed heights were designed primarily to accommodate medical examinations and nursing treatments, at a height so that nurses could lift patients without causing back strain or injury. However, this deck height was such that a step stool was sometimes required for patients to climb in and out of bed—thus resulting in a secondary hazard if patients subsequently slipped off the step stool. Further, a hazard existed should a patient roll out of bed from that height.

In 1948, Hill Rom developed the first variable height (*the Hi-lo*) adjustable bed.* Initially, the bed was hand-cranked (thereby increasing workload for nurses and in itself leading to back injuries); this system was subsequently replaced by a foot pedal. In 1952, the first variable-height electric motor bed was introduced, enabling the bed to be adjustable from a deck height of 17 in to 36 in. The low position was intended for patient ingress and egress, and the bed was adjusted to the high position for patient care and in-bed lifting. This low bed-deck height of 17 in remained the standard low height for all patients, regardless of patients' height or physical ability.

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* From brochure: "The Hill-Rom Difference" (No author, ND).

TABLE 20.1

Fall Rates by Institution Type for Decades 1980 to Present

	Acute Care		Rehabilitation		Nursing Home	
Years	**#/1000 pt bed days**	**Author (Year)**	**#/1000 pt bed days**	**Author (Year)**	**#/1000 pt bed days**	**Author (Year)**
1980–1989	2.3	Morse et al., 1989a	46/143	Mion et al., 1989	4.27	Berry et al., 1981
	3.35	Morgan et al., 1985			5.7	Myers et al., 1989
	2.18	Raz and Baretich, 1987				
	3.8	Llewellyn et al., 1988				
1990–1999	4.1,4.7	Kilpack et al., 1991	178/1000 pts per year	Vlahov et al., 1990		
	3.8	Cohen and Guin, 1991				
2000–present	2.3–7.0	Lake and Cheung, 2006	12.46	Forrest et al., 2013	3.73	Lake and Cheung, 2006
	3.6	Menéndez et al., 2013			17.9	Healey et al., 2004
	6.12	Hitcho et al., 2004			11.7[d]	Schwendiman et al., 2006
	9.6	Barnett, 2002				
	10	von Rentein-Kruse et al., 2007				
	9.1[a]	Schwendiman et al., 2006				
	11.3[b]	Dykes et al., 2010				
	2.9[c]					
	3.15–4.18					

[a] Entire sample.

[b] Internal medicine.

[c] Surgery.

[d] Geriatrics.

By 2000s, the concern regarding patients who "fell" out of bed while sleeping or reaching for objects resulted in a demand for low-low beds with a 6–10 in. deck height, which, while reducing injury resulting from "rolling" out of bed, results in an unstable sit-to-stand process and increased likelihood of falling on egress. In addition, beds at this height were biomechanically more stressful for attending staff.

20.2.1.2 Side Rails

Side rails were installed on hospital beds to prevent the patient from rolling out of bed. Initially, these attachments were used only when necessary to "confine" a restless or confused patient in bed, but later they were adopted as a standard part of beds in the United States, folding down for ingress and egress. However, these side rails failed as a method of *confining* a patient in the bed and did not serve as a restraint: patients climbed over the rail or over the end of the bed and fell. As rails increased the distance of the fall, they therefore increased the severity of injury. Another risk occurred when patients attempted to climb *through* the rails, suffocating or even being found hanging with their head trapped between the rails (Todd et al., 1997).

To prevent these accidents, the design of side rails changed over the decades. Originally, side rails were high and full length. In 1949, the first short side rails were developed but were installed on the beds as two partial-length rails.[2] Thus, even when rails were "split" length, when both sets of rails were raised, they could be used as full-length rails. Shorter side rails (¾ length) were safer, offering the patients a safe route to egress. When ¾-length split rails were used with the top rails up and the foot rails down, the top rails served to provide support for the patient's in-bed mobility and support (especially when the top of the bed was raised to a sitting position) as well as access to bed controls. Even so, side rails have now been removed altogether from beds in nursing homes. Most problematically, the absence of side rails interferes with and shortens the bed-alarm response time and removes the advantage of providing a hand support for the sit-to-stand process during egress.

The Food and Drug Administration (FDA) issued a warning regarding the safety of side rails (Burlington, 1995) and recommended regular inspection of all rails, bed frames, and mattresses. While federal regulations did not specify specific dimensions, recommendations included that

> Additional safety measures should be considered for patients identified as high risk for entrapment. Such patients include those with altered mental status (organic or medication related) or general restlessness. Increased risk also occurs when the patient's size and/or weight are inappropriate for the bed's dimensions. (Burlington, FDA, 1995)

Old-style rails were not withdrawn from circulation. Although caregivers may use full bed-length side rails as a restraint, the FDA noted that

> Bed side rails should not be used as a substitute for patient protective restraints. Patients who need a protective restraint, such as a vest or wrist/leg device, must be monitored frequently while wearing it. (Burlington, FDA, 1995).

Deaths from old-style side rails continued, with 550 deaths occurring between 1995 and 2011, mainly among those aged 60 or older and often with cognitive impairment. Although the style of rail was not recorded, incidents continued because of mismatch between the components of the rails, bed, and mattress in the case of "portable" rails; or in instances when there was a mismatch between these features and outmoded design. The systematic review conducted by these authors concluded that there was no evidence that bed rails affected falls from the bed or increased fall-related injuries (Healey et al., 2008). The design of side rails continues to be updated, and they are primarily used in acute-care and rehabilitation hospital beds.

20.2.1.3 Physical Restraints

In an attempt to prevent patients from falling out of bed or from climbing out of bed, until the late 1980s, patients were *tied* with restraints in the bed, in wheelchairs, or chairs. Patients considered at risk of falling were also restrained on toilet chairs or placed in chairs with tabletops fixed across their laps. The use of such restraints failed to meet the goal of keeping the patients safe. While patients were less likely to fall from beds or chairs, the restraints had other negative effects: they often made the elderly enraged at being "tied down." Fighting against the restraints and struggling to be free of the restraints even resulted in deaths from strangulation (Brush and Capezuti, 2001; Todd et al., 1997). In addition, those who were restrained lost muscle mass and experienced increasing weakness with forced bedrest; they also developed pressure ulcers and sometimes pneumonia.

In the 1990s, political action led by the Quakers in Philadelphia lobbied for the removal of restraints. In addition, researchers documented patient responses to being restrained (Morse and McHutchion, 1991) and staff attitudes to restraints (Bourbonniere et al., 2003). Researchers also developed programs demonstrating that safe care could be provided without restraints. Kayser-Jones (1990) documented the safe care of the elderly in Scotland, where restraints were not used. Gradually, political pressure resulted in legislative recommendations against the use of restraints and side rails in nursing homes (Capezuti et al., 2007), without a physician's order, and frequent surveillance.

20.2.1.4 Pharmaceutical Restraints

As physical restraints were used less frequently, there was an increase in the use of medication to keep patients, quiet, sedated, and in bed. One side effect of these drugs was the fact that they increased the patient's fall risk by impairing gait and balance and causing postural hypotension and therefore increasing fall risk. In-bed patients were less likely to move so that the iatrogenic risks of bed rest were increased. Thus, chemical restraints as a fall intervention were discouraged, and the definition of a *restraint* was expanded to include chemical restraints (Mott et al., 2005).

20.2.1.5 Bed Alarms

As restraints were removed, concern about patient management and the prevention of falls became a primary concern. One technical intervention was the development of bed alarms to alert the nurse when a patient moved to the side of the bed to egress. The first of these alarms was a workaround developed by nursing staff—simply pinning a patient's call bell to his or her gown. Then as the patient moved forward to climb out of bed, the call bell pulled from the wall connection, sounding the emergency alarm.

Bed alarms have evolved through various styles and modes of operations since the early 1980s (see List 20.2).

LIST 20.2

Development of Bed Alarms (1980–present)

1982: Air pressure alarm: a sensor under the end of the mattress and an air pressure switch

1985: *Ambularm*: A mercury switch worn on the patient's thigh, which sounded as the patient stood up (http://www.familymedsupply.com/Catalog/Online-Catalog-Product/1346/Ambularm1000)

1985: Prototype of the *Bedcheck* alarm, a pressure-sensitive strip across the top of a mattress or seat or the chair

1985: Bed alarms built into the bed (NA, Hill Rom)

2004: Video alarm systems (Cucchira et al., 2007; Sixsmith and Johnson, 2004)

These alarms all shared a common problem: while alarms proved reliable in laboratory testing, they were not feasible in practice; that is, when a bed alarm sounded to indicate that a patient was getting out of bed, nurses had only 9 s or less to reach the bedside in order to support (i.e., "catch") the patient. Obviously, nurses were often not available or close enough to reach the patient before the fall occurred, especially if the patient had impaired gait or balance. Later, alarms could usually be programmed to give the patient instructions ("Hold on—I am coming!") in an effort to reach the patient in time.

20.3 Present Fall Intervention Programs

Since 2000, fall intervention programs consist of three arms: (1) fall triage to identify the patient at risk of a physiological anticipated fall, (2) fall prevention strategies, and (3) fall protection strategies.

20.3.1 Triage of the Fall-Prone Patient

The Joint Commission's 9th National Patient Safety Goal was "Reducing the risk of harm resulting from falls to inpatients and nursing home residents":

> Falls account for a significant portion of injuries in hospitalized patients, in long term care residents, and home care recipients. …the organization should evaluate the [patient's] risk for falls and take action to reduce the risk of falling, as well as the risk of injury should a fall occur. (Joint Commission, 2009)

The Joint Commission required institutions to "evaluate the [patient's] risk for falls" (p. 22) using short instruments designed to triage the fall-prone patient and to "take action to reduce the risk of falling, as well as the risk of injury" (p. 22). The major scales used in the United States are the Morse Fall Scale (MFS, of 6–10 items) (Morse et al., 1989b; Morse, 2007); Hendrich II, of eight items (Hendrich et al., 2003); and, in Britain, the STRATIFY scale, of five items (Oliver et. al., 1997), developed for use in nursing homes. The MFS and the Hendrich II were developed both by the identification and weighting of the items from a comparison of patient falls and a control group. The weights (i.e., scores) for the STRATIFY scale were subjectively selected until 2004, when added weighted scores were added (Papaioannou et al., 2004). Other scales in use have been developed statistically but have the item *weights* subjectively assigned, for instance, the Downton Index, Hendrix I, Fall Prediction Index (Nyberg and Gustafson, 1997), and Scott & White Risk Screener (Yauk et al., 2005). In many cases, scales have been constructed qualitatively by identifying items from the literature, by freely adapting or combining other scales, or by using the nurses' "intuition" (Oliver, 2006, 2008; Uden et al., 1999). Item scores are also subjectively assigned (Kelly and Dowling, 2004). Although some of these may have been published in clinical journals, no reliability or validity statistics are available.

While triage scales are intended to identify the fall-prone patient and predict a fall, the main limitation is that the scales themselves do not prevent the fall—the fall interventions do. Problematically, these two major areas of fall prediction and fall intervention have not been systematically linked. That is, while we can now predict with reasonable accuracy the patients or residents who are likely to experience a physiological anticipated fall, the recommendations for fall intervention strategies remain subjective, haphazard, and undifferentiated and, at best, linked to categories of fall risk (high, medium, or low fall risk) rather than being associated with or linked to particular patterns of fall risk scores, (i.e., *patient fall profiles*) and items scored on the triage scales. Clearly, until intervention strategies are applied appropriately and consistently to particular patterns of patient profiles, fall intervention programs will remain unnecessarily expensive, fall strategies will be applied unnecessarily or will not be applied at all, and programs that are less than optimally effective will place patients at risk of injury from falls.

Fall prevention strategies are those intended to *prevent the patient from falling.* Unfortunately, there is confusion about the risk of a *fall* per se: Some institutions score infants and small children for anticipated physiological falls, yet their own records would show that these children are prone to injury from *accidental falls* (not anticipated physiological falls). They usually fall while climbing on playroom equipment, from cribs, or, as mentioned previously, when dropped by caregivers. Many nursing homes and rehabilitation units also recognize that overprotection may result in *fear of falling* (Zijlstra et al., 2007) and argue that the patient has a "right to fall," and must fall, if they are to rehabilitate. For these reasons, fall protection strategies are a primary concept in nursing homes and rehabilitation hospitals, and fall prevention strategies are of primary significance in acute-care institutions.

20.3.2 Fall Prevention

Fall prevention strategies are twofold: (1) environmental scans to remove the risk of an accidental falls, and (2) prevention strategies, or interventions, to *prevent* the patient from falling.

20.3.2.1 Environmental Scan

The environmental scan is an annual walk-through of an institution to inspect the institution hazards that may result in an accidental fall. The nurse specialist responsible for falls, the chief nursing officer, the chief engineer, and the head of housekeeping carry out the inspection. As this team moves into each unit, the head nurse for that area joins them. During the inspection, there is

- A random inspection of beds, wheelchairs, waking aids, and other equipment
- Inspection of patient rooms for the "flight path" between the bed and the bathroom, absence of clutter, and availability of walking aids and rails

- A visual inspection of bathrooms, positions of rails, flooring, security of shower curtains, ledges on the floor to contain water but that may also trip patients, and so forth
- Inspection of hallways for use of nonglare floor sealer, handrails, and clutter

20.3.2.2 Fall Prevention Strategies

Fall prevention strategies may be classified into those that enhance patient vigilance and those that are intended to prevent a fall. For example, some patient vigilance strategies *monitor the patient* by facilitating nurse surveillance of the patient and work by alerting the nurse when the patient is restless and egress is inevitable. Sometimes, hospitals employ *sitters*—people with minimal training who are employed to watch the patient and to call the nurse if the patient tries to get out of bed. Evaluating the need for and the activities of sitters, Tzeng et al. (2008), found that sitters were an alternative to the use of restraints but that fall rates were higher when sitters were used. Hiring sitters is expensive; many large urban medical centers spend more than $1,000,000 per year. At other times, hospitals may request that a relative sit with their loved one, also to monitor against falls. Many hospitals are now instituting *comfort rounds*, one- or two-hourly checks on all patients to see if they have bathroom or other needs (Tzeng et al., 2008).

Bed alarms are the most common methods of increasing patient surveillance. They now are available in various styles:

- An alarm built into the bed, which alarms when the patient's weight moves off the edge of the bed
- A separate pressure-sensitive strip placed under the patient's sheet, which alarms when the patient's buttocks move off the strip
- A clip attached to the patient's shirt, which alarms when the magnet detaches from the alarm as the patient moves out of bed
- An infrared beam detector, which alarms when the patient moves to the perimeter of the bed

Bed alarms may sound in the emergency call bed system or at the bedside. They may even have recorded announcements providing the verbal instructions "Get back to bed," or "Hold on and stand still." While these alarms pass the manufacturers' tests for reliability, they are subject to human error: staff forget to turn them on, staff do not hear the alarm, or staff cannot get to the patient in time to prevent a fall—it generally takes only 9 s for the patient to get out of bed.

Capezuti et al. (2009) conducted a study testing two types of bed alarms in a nursing home: a pressure-sensitive strip and a pressure-sensitive strip combined with an infrared beam. They concluded that the combined alarm reduced false alarms but that neither alarm was "a substitute for staff availability." This conclusion was endorsed by Hubbartt et al. (2011), who reported that the "University Health System Consortium (UHC) Patient Safety Net" aggregated falls data for 2008 examined more than 20,000 submitted fall reports that occurred in 2008 in 39 organizations. Data showed that bed-exit alarms were one of the fall prevention strategies in place at the time of the fall in the case of more than 3000 fallers, and that the UHC did not find any evidence supporting the use of monitoring devices (bed/chair or exit alarms) in preventing falls. However, the UHC also noted that "alarms on" were associated with a "slightly lower percentage of harmful events (11.4%–12%)

among those who fell" (Aggregated data, Web seminar report, University Health System Consortium, 2009, in Hubbartt et al., 2011, p. 199).

Side rails are intended to prevent the patient from rolling out of the bed and to provide support and a handhold as patients exit the bed. At first glance, this appears to be logical fall prevention strategy. However, as noted earlier, historically the side rail was a hazard, leading to strangulation. A British study by Healey et al. (2008) noted that problems with bed rails were due to outmoded designs and "incorrect assembly" and that "bed rails do not appear to increase the risk of falls or injury from falls" (p. 368).

Despite this resistance, side rails continue to be manufactured on beds and used primarily in acute-care and rehabilitation hospitals. A study showing how the rails may be used during ingress, egress, and turning will be discussed at the end of this chapter.

Video surveillance for general observation of the patient is relatively new—especially in patient rooms. Software has only recently been developed that will protect the patient's privacy by altering the image. Video technology allows the visual inspection of the bed with an alarm sounding if the patient breaks the perimeter of the bed, and enables the visual inspection of the bed from the nursing stations.

Walking aids include canes, crutches, and walkers that support the patient during ambulation. If used correctly, they reduce the patient's risk of falling. However, if the patient forgets to use the cane or walker or uses it incorrectly, the patient may fall. Thus these walking aids are not suited to patients with impaired cognition. Hand rails on the walls of bathrooms, patient rooms, and corridors may also be considered walking aids that support ambulation and prevent falls. Because they are always in place and do not require technology, they may be considered a *passive intervention.*

20.3.3 Fall Protective Strategies

Fall protection strategies are intended to *prevent injury* should a fall occur. From this perspective, the patient is permitted to ambulate, and the side effects of immobility are prevented. Alternatively, if the patient does make an illegal exit from the bed and fall, injury is minimized.

20.3.3.1 Hip Protectors

Hip protectors are items of underwear with pads that fit over each hip. They were originally plastic shields, but later, for reasons of in-bed comfort, they were made from dense foam. The pads fit over the hip and are inserted into underwear, so that if the patient falls sideways, the hip is protected and the impact on the hip is minimized. Early reports of hip protectors suggested they were effective, and they were adopted into nursing homes. However, more recently, their efficacy has been questioned.

A Cochrane review of nine randomized studies and six cluster randomized studies revealed that the "original protective effect was not confirmed in individually randomized studies… but marginal significance effect of hip protectors on reducing the incidence of hip fracture amongst participants in nursing homes and in residential care" (Parker et al., 2005, p. 8 was obtained).

20.3.3.2 Helmets

Helmets come in two forms: a hard helmet (rather like a bicycle helmet) and a "soft" helmet that may be used in bed, while sleeping. Helmets are primarily used by epileptics to protect the head during a seizure, and those who need helmets may refuse to wear them.

20.3.3.3 Floor Mats

Floor mats are padded mats placed beside the bed, so that if a patient rolls out of bed, the impact will be lessened and the opportunity to fracture a hip reduced. Independent tests in a laboratory (Bowers et al., 2008) using mannequins and simulated falls from six heights, both head and feet first, onto a tiled floor and onto a floor mat showed that both a low bed height and a floor mat decreased the risk of injury when falling from a bed.

However, in a study published by Doig and Morse (2010), it was noted that the beveled edge of the mat produced a hazard when patients walked across the mat, particularly when entering the bed. The patients experienced instability when their heels were placed on the beveled edge of the mat. This caused patients to stumble and presented a fall risk. It was recommended that the mat not be used.

20.3.3.4 Rails

There has been considerable amount of research conducted into the optimal height and circumference of rails. While dimensional and installation guidelines are provided in reference material, it is important that hand supports be designed and installed to facilitate use by those with reduced grip strength. This is required to prevent instability and increase the likelihood of fall arrest in the case of a fall initiation. It has also been found that the preferred positions of hand supports for toilet use by the elderly depends on individual preferences (Dekker et al., 2007). Railings are usually found in bathrooms and hallways. Oddly, they are not routinely installed in bedrooms, where they may be most needed. It is proposed that the use of grab bars on every patient-room wall would facilitate movement from the bedside to the bathroom (Tzeng and Yin, 2010).

20.4 Therapies to Reduce Risk of Falling

Fall risk assessment is an examination of the patient, by a physical therapist or a physician, to determine if the patient has a medical diagnosis that may be contributing to the fall-prone behavior or if the patient would benefit from exercise therapy (Tinetti et al., 1986). It differs from fall triage, as it seeks to uncover the *cause* of the fall-prone behavior and prescribes physical therapy or medications to correct deficits.

20.4.1 Vitamin D

There has been no evidence of the efficacy of vitamin D supplementation for the geriatric populations overall, although a subgroup with vitamin D sufficiency did show a significant reduction in the rate of falls (Gillespie et al., 2009; Kalyani et al., 2010). In one case, Cameron et al. (2010, p. 16) showed a significant positive effect of vitamin D supplementation on the rate of falls (0.57 [95% CI 0.37–0.89]) and the risk of falling (0.65 [95% CI 0.46–0.91]).

20.4.2 Muscle Strengthening

Because of the short length of stay in hospitals, strengthening exercises are not usually a part of therapy. However, physical therapy has shown that muscle strengthening has beneficial effects, improving gait and balance in the fall-prone elderly. A randomized control trial of the Otago home-based program showed a reduction in physiological fall risk and an improvement of functional mobility and executive functioning in older adults over a period of 6 months (Lui-Ambrose et al., 2008). In this study, 43% of the fall group and 67% of the control group fell, showing that a home-based exercise program significantly reduced fall risk.

Tai chi is another strategy used to improve balance and cardiorespiratory function and to reduce falls in the elderly. However, a systematic review (Verhagen et al., 2004) consisting of seven studies and 505 participants determined that evidence was "limited" in reducing falls and blood pressure in the elderly.

20.5 Summary

While these three approaches (fall prevention, fall protection, risk reduction therapies) form a logically complimentary fall intervention program in health-care institutions, there are tensions between these three facets of fall interventions. Researchers have tried to assess the efficacy of each intervention separately, but in reality, patient falls are caused by multiple factors. At the center is human error on the part of both the patient and the caregivers. Patients are expected to call for help before they get out of bed, yet this expectation is unrealistic. Patients are in a hurry to get to the bathroom; they do not want to be assisted with this intimate task and do not feel that such assistance is necessary. Nurses are busy with a large caseload and cannot immediately respond to calls for help or call bells or even be responsible for vigilantly and constantly observing patients. Institutions cannot afford one-on-one sitters for all restless patients. Correcting fall proneness using physical therapy or medication such as vitamin D or by correcting drug interactions to prevent hypotension or confusion are not usually immediate fixes.

Considering the *Swiss Cheese* model of causation (Reason, 2000), falls occur when series of factors "line up" (like the holes in Swiss cheese) and sequentially allow a series of events to lead to an accident. For instance, the patient climbs out of bed; the bed alarm fails or is not turned on, or the nurses cannot reach the bed in time. The patient is incontinent and slips on the urine; he then falls backward and his head hits the floor, fracturing his skull.

Astonishingly little attention has been given in the hospital environment to making the bed safe should a patient egress, placing rails and handholds in the patient's room, and attending to hazards in the bathroom. Ergonomic research and biomechanical solutions to making in-bed mobility easier, bed exit safer, and the route between the bed and the bathroom less hazardless appear to be the next step in fall intervention programs. This approach is addressed in the next section.

20.6 Review of Research Related to Biomechanical Parameters

Biomechanics, or the application of the basic principles of physics and mechanics to the biological system, is not new. A review of the notebooks of Leonardo da Vinci indicates that as early as the fifteenth century, scientists recognized the importance of understanding the physics and mechanics of living organisms. Biomechanical principles have been used in the analysis of how humans interact with their working and living environment. In this section, we discuss areas of research that would make the hospital environment safer and biomechanical research performed relating to human safety in the health-care setting. This discussion starts with a brief review of how biomechanics has been used in the analysis of patient handling. The section then focuses more specifically on the elderly and deals with the biomechanical analysis of mobility and gait, slips/falls and the potential for injury, and fall recovery/injury prevention in the hospital. We conclude with an example of such research—an interim report of a major research effort funded by the Agency for Healthcare Research and Quality (AHRQ) to determine the effect of bed design on slip/fall potential in a diverse group of older disabled adults.

20.6.1 Biomechanical Analysis of Patient Handling

Biomechanical principles have been used extensively in the analysis of the injury potential in persons handling or assisting patients in the health-care environment. In a comprehensive analysis, Marras et al. (1999) used a risk analysis and a biomechanical spinal loading model to evaluate the risk of low-back disorders in participants performing patient transfer and repositioning tasks carried out by one and two people. They found that, even with a light and cooperative patient, these tasks were "extremely hazardous" with a "substantial risk" for low-back injury, even when performed by two people. In a biomechanical analysis of patient transfer from bed to wheelchair and wheelchair to bed, Garg et al. (2007) found that pulling techniques required significantly lower hand forces and significantly lower low-back compressive forces than lifting techniques. They found that low-back shear forces and trunk moments were lower, and the percentages of females able to perform the tasks were higher, for pulling than lifting techniques.

In a biomechanical analysis of patient transfer from shower chair to wheelchair and wheelchair to shower chair, Garg et al. (2007) found that techniques based on pulling the patient resulted in lower trunk-flexion moments, erector spinae muscle forces, compressive forces, and shear forces than techniques utilizing lifting. Biomechanical analysis has also been used to evaluate the effectiveness of mechanical patient handling systems. In an evaluation of lift-assist systems, Keir and MacDonell (2007) found that erector spinae, latissimus dorsi, and trapezius muscle activity was lower during the use of the ceiling lift than during the use of the floor lift. Silvia et al. (2002) performed a biomechanical analysis of a manual patient transfer using a sling suspension lift (similar to a "Hoyer" lift) and a novel system involving a translation of the bed sheet to a gurney that converts to a moveable chair. They found that both mechanical systems resulted in lower back-compressive forces than manual patient transfer.

20.6.2 Biomechanical Analysis of Elderly Mobility and Gait

Biomechanical analysis techniques can be used to describe and quantify mobility issues in the elderly. In a detailed analysis, Schultz (1992) reviewed the potential for biomechanical analysis to quantify changes in gait, fall potential, and difficulty in bed and chair transfers as a function of increasing age. He notes that "physical disabilities ultimately express themselves as changes in the biomechanics of physical-task performance" and emphasizes that the needs for biomechanical research into mobility impairment in the elderly "clearly constitute new and major challenges for biomechanics research." Older participants slipped longer and faster and fell more often than younger subjects, and changes in gait as a function of age (particularly higher heel-contact velocity and slower movement of the center of mass of the upper body) may increase slip potential (Lockhart et al., 2003). It is interesting to note, however, that in an analysis of the biomechanical walking patterns of fit, when compared to a database of young adults, elderly adult subjects demonstrated shorter step length, increased double stance-support stance period, decreased push-off power, and more flat-footed landing, all of which are indicators of a more stable and safe gait pattern (Winter et al., 1990). Clearly, this is a fertile area for additional research.

20.6.3 Biomechanical Analysis of the Potential for Injury in Slips/Falls of the Elderly

In a biomechanical analysis of the injury severity potential resulting from falls from the bed onto a mat and hard floor using mannequins, Bowers et al. (2008) found that the likelihood of a serious head injury resulting from a feet-first fall from a bed height of 38.4 in. (97.5 cm) onto a tiled floor was 25% and approximately 1% when falling onto a mat. In a review of fall-impact biomechanics, the peak impact forces of a fall from standing height averaged 1260 lb (5600 N), which is well above the 900 lb mean force required to fracture the femur in an elderly person (Robinovitch et al., 2000). These authors also suggest that compliant surfaces can reduce the potential for wrist injuries during a fall from standing height or lower.

20.6.4 Biomechanical Analysis of Fall Recovery/Injury Prevention for the Elderly

Biomechanical research and analysis can be used not only to quantify slip-and-fall potential but also to minimize the adverse effects of these events. In a review of biomechanical issues related to age-related upper-body injuries in older adults, DeGoede et al. (2003) note that there is evidence that fall-related impact forces can be reduced by appropriate volitional strategies. They also suggest that further experimental and theoretical research is needed to determine the best fall-arrest strategies for older adults. In a discussion of the prevention of fall-related fractures through biomechanics, Robinovitch et al. (2000) suggest that "safe landing responses" may be an effective way to reduce injuries resulting from falls. Grabiner et al. (2008) discussed the translation of experimental biomechanical results to the clinic setting. They found that through task-specific training, elderly adults can be taught to limit trunk motion, and this learned motor skill has been shown to decrease the likelihood of a trip/fall risk. They conclude that traditional exercise-based fall prevention training can reduce fall-related injury in older adults.

Liu and Lockhart (2009) performed a biomechanical analysis of successful recovery from slips and found that there were age-related differences in joint moments during the recovery action. DeGoede and Ashton-Miller (2003) performed biomechanical simulations of forward fall arrest and found that the age-related decline in arm-muscle strength substantially reduces the ability to use the arms to arrest a fall and increases the potential for torso or head impact. They also note that elderly women with below-average bone strength are at risk of a colles fracture (fracture of the distal radius in the forearm) if they attempt to arrest a fall with an extended arm. In a biomechanical analysis of fall arrest, Kim and Ashton-Miller (2003) indicate that any fall prevention strategy that increases the time available for arm movement prior to impact would help reduce fall injuries, particularly for older males. In an analysis of the effects of ageing on slip/fall biomechanics, Lockhart et al. (2005) propose that the ability to recover from a slip is lower in the elderly due to reduced lower-extremity strength and sensory degradation. Interestingly, in a biomechanical analysis of lower-extremity joint moments, Wojcik et al. (2001) did not find conclusive evidence that age-related decline in lower-extremity strength was associated with a decreased capacity of adults to recover their balance after a forward fall. In a somewhat different approach, Gatts and Woollacott (2006) analyzed the biomechanics of recovery after a slip and found that, for gait-impaired seniors, Tai Chi training resulted in an increase in the ability to control stepping strategy and center-of-mass anterior–posterior motion, two key balance-control mechanisms.

There is a need to place what is known in the context of the hospital room and the patient's problem of safely moving off the bed, standing, and moving across the room to the bathroom.

20.7 Application of Biomechanical Research to the Hospital Bed, the Hospital Room, and the Bathroom

At the beginning of this chapter, we noted that each year in the United States, almost 200,000 hospital patients are seriously injured. In the previous sections, we noted that a great deal was known about the biomechanical movements of the elderly and disabled and fall proneness. But when hospitalized, the environment is planned for the movements of staff, that is, the space required for patient transfer and for caregiving. Little research has been done into the way patients may safely ambulate away from the bed; relatively little is known about the biomechanics and mobility support needs of safely "getting to the bathroom."

20.7.1 Bed Height and Safe Egress

As noted previously, bed height has changed over the past five decades, but beds are still constructed according to standards of "one size fits all." That is, despite the ability to adjust the height, the low height is usually approximately a 16 in. deck height for all patients (Morse et al., 2015). Yet research related to the safe bed height for ingress or egress according to individual disability, and anthropometric measurements had not been conducted, and results from an ongoing study are not yet available. Interim results are presented in Box 20.1.

Our interim results show that the lowest height of the bed must be adjustable, so that caregiver may "set" the low height for the patient who is entering and for exiting. Once these two standard measures are known and may be adjusted for each individual and the bed height "set" accordingly, falls from the bed while exiting will be reduced. Patients will be less likely to slip and will maintain better balance when exiting the bed or slip from the deck while entering (Chrisman et al., 2015). As most falls in the hospital involve the bed, injuries will be dramatically reduced.

20.7.2 Balance/Support on Standing

When patients exit the bed, there is nothing to provide balance support except the bed rail. These rails have 2–3 in. of "play" and, despite their strength, they *feel* to be a poor support to the patient. The gap across the floor from the bed to the bathroom door has been measured up the 16 ft without a handhold—much too far for a patient with an impaired gait to navigate.

BOX 20.1 EXAMPLE: BIOMECHANICAL AND ERGONOMIC ANALYSIS OF THE EFFECT OF BED HEIGHT

Interim Report of AHRQ #1R01HS018953-01, Linkages Between the Safety of the Hospitals Bed, patient falls and immobility (Morse et al., 2015)

BACKGROUND

The work noted above was the impetus for a comprehensive study into biomechanical parameters and other issues related to slip/fall risk for the elderly during movement to bed, bed entry, repositioning in bed, bed exit, and movement away from the bed in a simulated health-care setting. The major goal of this research effort is to determine the effect of bed height on biomechanical parameters and slip/fall potential during the above activities for fall-prone and control elderly subjects. Bed heights were set as low, medium, and high and were represented by 95%, 110%, and 125% of the lower leg length with lower leg length defined as by a measurement that is taken to the tibial plateau with the knee at 90° and the foot flat on the floor.

SUBJECTS

The present analysis is based on a subject population of 53 older adults ranging in age from 50 to 95 (mean = 59.3, SD = 10.6), with a Morse Fall Scale (MFS) (Morse, 2009) range from 15 to 100 (mean = 59.3, SD = 20.7). Height and weight ranged from 153.7 to 194.3 cm and 60.3–153.7 kg respectively, and the BMI ranged from 18.2 to 46.9 (mean = 29.4, SD = 5.7). Within the total subject population, 36 were categorized as "fall-prone" or "at risk" of falling (MFS >45 and/or significant gait and mobility impairment) and 17 were controls. Exclusion criteria were (1) unilateral strength deficit > 50%, (2) lower limb amputations, or (3) height >200 cm or other medical conditions (morbid obesity, osteoporosis) that prevented the use of the fall arrest system. Descriptive information for the fall-prone subjects: average age of 69 (SD = 12), average height of 172.2 cm (SD = 10.7), average weight of 88.4 kg (SD = 21.9), and average MFS = 67 (SD = 13.6). Descriptive information for the control subjects: average age of 65 (SD = 10.6), average height of 174.0 cm (SD = 7.9), average weight of 83.0 kg (SD = 16.3), and average MFS = 32 (SD = 8.4).

METHODS

The study was conducted in a biomechanics laboratory created specifically for this project at the George E. Wahlen Salt Lake City Veterans Administration Hospital. Two force plates were installed flush with the floor next to the bed and one force measurement system was mounted to record forces applied to the hand rails. Three-dimensional body motion data was captured from 70 retroreflective markers on key anatomical landmarks and limb segments. The combination of force plate and motion data allowed the calculation of shear forces at the foot–floor interface, joint torques, and parameters related to balance. To prevent falls, all subjects wore a safety harness attached to a climbing rope with a locking carabiner and were belayed from a steel frame. A registered nurse monitored each subject's stability prior to and during each trial and stopped the trial if a subject demonstrated excessive fatigue or indications of balance loss or instability.

(*Continued*)

BOX 20.1 (CONTINUED) EXAMPLE: BIOMECHANICAL AND ERGONOMIC ANALYSIS OF THE EFFECT OF BED HEIGHT

RESULTS

Results to date indicate that for bed entry, the high bed presented the greatest slip potential and the low bed presented the least as it relates to the frictional forces at the foot–floor interface. For bed exit, the low bed presented the greatest slip potential using this same measure. The time to first step after bed exit, which may be a measure of stability, was the longest for the low bed and shortest for the high bed. The low-height bed required greater joint moments in the lower extremities. Participants with lower leg strength used movement patterns that increased the slip potential at the foot and increased leg strength moment requirements, both of which are potential indicators of increased slip or fall potential.

In summary, it is proposed that bed height should be adjusted for different patients to reduce slip/fall potential. Low beds required greater effort to rise and reduced slip potential on ingress. High beds made it difficult to sit securely on ingress but reduced slip potential and required effort on egress.

It is unrealistic to expect a patient—in particular a patient with cognitive impairment—to remember to stay in bed when instructed. It is therefore our responsibility to provide a means for safe exit from the bed and a safe path from the bed to the bathroom. There is a need to provide a support/handhold for the patient when moving from sitting to standing from the bed. There is a need to provide rails and/or a walking frame for the patient who is moving unassisted to the bathroom. Such engineering/architectural developments would greatly decrease fall rates, providing support for the patient with poor balance and giving the nurse time to respond to the bed alarm.

20.7.3 Rails in Patients' Rooms

Hospitals provide miles of rails in corridors "to protect the walls." The rails are usually 10 in wide and flat, with a curved top that serves as a hand hold. Despite the extensive research of Maki and McIlroy (2006) on the dimensions and height of the rails, these commonly used rails do not meet their specifications and do not even have a place for a thumb grip to provide adequate support. In addition, often there are no rails in patients' rooms, forcing patients to grasp at other items on the walls for support—computer trays, thermostats, glove and mask boxes, and so forth. These items, acting as "substitute rails," have not been installed to bear the patient's falling weight, nor do they provide stable support.

20.8 Bathrooms

A large percentage of falls occur in the bathroom as a part of toileting or showering. In older hospitals in particular (those built before 1960), fixtures are installed for a person who is standing. Mirrors are too high for patients to use while sitting; rails are located in less than optimal positions to provide support when a patient moves around the room.

20.8.1 Floor/Standing Surfaces

The prevention of the initial foot slip is important in the reduction of falls in the bathroom. This can be accomplished through the use of floor materials that have a high coefficient of friction (CoF) (Rubenstein et al., 1996) and retain this high CoF when wet (Tideiksaar, 1989) and, if possible, even when soapy. Bowen (1993) found some floor materials that have a higher CoF with a bare foot when wet than when dry. Kim et al. (2009) found that slippery floors (OR = 12.130) and bathroom mats without rubber backing (OR = 3.564) were risk factors for slips for the elderly. The use of skid-resistant backing on bathroom rugs and skid-resistant adhesive appliqués can reduce slip potential (Rubenstein et al., 1996; Tideiksaar, 1989).

In an attempt to reduce injury in impact, Casalena et al. (1998) explored different floor surfaces, but surfaces that are both resilient enough to managed wheeled carts and beds and soft enough not to drag on patients' feet, and that can withstand daily wear while providing adequate absorption from fall impact, have yet to be developed.

20.8.2 Hand Rails

Because of the potential for slip and the presence of hard surfaces, hand rails or grab bars are particularly important in the bathroom. It has been found that when adequate hand rails are not available, people tend to use hazardous supports to facilitate bathing and toileting (Aminzadeh et al., 2000; Tideiksaar, 1989). Recommendations on the use of hand rails in the bathroom are ubiquitous and have existed for many years (Tideiksaar, 1989; Rubenstein et al., 1996; Tzeng and Yin, 2010; Woodson, 1981; Panero and Zelnik, 1979). When they are available, it is critical that bathroom handrails are secure. Loose or wobbly grab bars have been associated with a risk ratio of 7.83 for first falls in the elderly (Northridge et al., 1995).

20.9 Conclusions

Despite awareness of the human and economic cost of patient falls in institutions and administrators', caregivers', and researchers' efforts to reduce the risk of falling, we are still far from the goal of providing a safe yet therapeutic environment in hospitals. Research conducted for more than six decades has altered the pattern of patient falls but has not reduced the rate of falls and fall injuries. We can predict an anticipated physiological fall with some accuracy, but we still do not know how to prevent the fall from occurring. There is a need for large-scale research projects that develop a comprehensive and innovative approach to fall interventions.

We now recognize that hospitals should provide all patients with a safe route of egress that extends from the bed to the bathroom. Smart beds have been developed, with sensors to detect when occupied or unoccupied and automatically reset brakes. These features must be extended to automatically reset to the safest height for ingress and egress according to individual patient specifications. There is a need to develop an innovative room layout so that patients do not have to negotiate distances without handholds or other supports. Caregivers must be provided with sensors and alarms so they may monitor the location of patients, in particular those with unsteady or impaired gaits, hypovolemic incidences, or other physiological occurrences that may result in falling. These sensors should prompt caregivers to help with patient toileting and exercise needs and provide regular social contact. Caregivers must know where patients are, be alerted to their needs, and automatically record caregiver contacts.

In summary, most fall intervention research has been approached from the caregiver perspective: identifying the fall-prone patient, *preventing* the patient from falling, and *protecting* the patient from injury. Biomechanical and ergonomic researchers have explored lifts and mobility aids, gait, the mechanism of slips and falls, and fall injury causation. But these various branches of research have not been coordinated in a systematic review of all of the noted factors and implementation of research results into the design and use of patient care facilities.

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