Interventions for Preventing Falls in Acute- and Chronic-Care Hospitals: A Systematic Review and Meta-Analysis

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OBJECTIVES: To determine the characteristics and the effectiveness of hospital fall prevention programs.

DESIGN: Systematic literature search of multiple databases (Medline, Cinahl, Precinahl, Invert, the Cochrane Library) and of the reference list of each identified publication.

SETTING: Inclusion of prospective controlled-design studies reporting the effectiveness of fall prevention programs in hospitals.

PARTICIPANTS: Two reviewers.

MEASUREMENTS: The methodological qualities of the studies were assessed based on 10 criteria. For the meta-analysis, the relative risk of a fall per occupied bed day (RR_{fall}) and the relative risk of being a faller (RR_{faller}) were calculated.

RESULTS: Eight studies met the inclusion criteria, of which four studies tested multifactorial interventions. Although these studies took place in hospitals, most were conducted on long-stay (mean length of stay (LOS) >1.5 years) and rehabilitation units (mean LOS 36.9 days). For analysis of the number of falls, one unifactorial and two multifactorial studies showed a significant reduction of 30% to 49% in the intervention group, with the greatest effect obtained in the unifactorial study that assessed a pharmacological intervention. The pooled RR_{fall} for the four multifactorial studies became nonsignificant after adjustment for clustering ($RR_{fall} = 0.82$, 95% confidence interval (CI) = 0.65–1.03). No studies reported a significant reduction, either single or pooled, in the number of fallers in the intervention group (pooled RR_{faller}-0.87, 95% CI = 0.70–1.08).

CONCLUSION: This meta-analysis found no conclusive evidence that hospital fall prevention programs can reduce the number of falls or fallers, although more studies are needed to confirm the tendency observed in the analysis of individual studies that targeting a patient's most important risk factors for falls actively helps in reducing the number of falls. These interventions seem to be useful only on long-stay care units. **J Am Geriatr Soc 56:29–36, 2008.**

Key words: accidental falls; prevention; inpatients; hospitals; meta-analysis

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Falls frequently occur in hospitals, and the patients most likely to fall are older inpatients.[1] Approximately 2% to 12% of patients experience at least one fall during their hospital stay.[2,3] On stroke rehabilitation units, fall rates may climb to 46%.[4,5] The literature on hospital falls shows great variability in the incidence of falls (2.2–17.1 falls per 1,000 patient days), depending on ward type and hospital population.[6–8] Mainly older patients (aged ≥65) are affected, sometimes incurring serious injury from a fall.[9] Direct consequences of a fall can vary from bruises and minor injuries (28%) to severe wounds of the soft tissues (11.4%) and bone fractures (5%).[10] A hip fracture is the most serious complication; in 20% of the cases, such a fracture leads to immobility, and in 14% to 36% of the cases, it leads to death within 1 year.[11] These complications often result in a longer length of stay[12] and lead to greater healthcare costs.[13] They can even have legal consequences.[14] Moreover, patients who have experienced previous falls frequently develop a fear of falling, which may contribute to decreased mobility and increased dependence of care.[15] Nursing staff and patients' families are often confronted with feelings of guilt and anxiety.[16] Therefore, fall incidents and their negative outcomes represent a considerable problem in hospitals and require implementation of a strategy to prevent these undesirable events.

A Cochrane review[17] of fall prevention in elderly people found that effective fall prevention programs exist for elderly people living at home or in residential institutions but not for elderly people in hospitals. In a meta-analysis[18] of hospital fall prevention programs, a pooled effect of an approximately 25% reduction in fall rates was found, but this result was based on reviews of studies that used the less-powerful prospective method with historical controls. The few randomized, controlled trials reviewed in that

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meta-analysis showed no significant benefit. In addition, it was unclear what constituted the samples, and the description was vague, failing to list criteria for inclusion and exclusion of studies and to consider the quality of the studies. All of these limitations weakened the conclusions.

Because of the limitations of and the limited evidence presented in previous reviews, a fresh literature review and meta-analysis was conducted that included information from recent research reports on new interventions. The objectives were to determine the characteristics of fall prevention programs in hospitals; how these programs affected the number of falls, fallers, recurrent fallers, fall-related injuries, and the time to first fall; and whether the programs showed adverse effects.

METHODS

Search Strategy

The identification of relevant studies was performed in two steps. First, a thorough search was conducted of the databases Medline, Cinahl, Precinahl, Invert, and the Cochrane Library for pertinent articles published between January 1966 and June 2006. Key words for the search were "accidental falls," "falls," "prevention and control," "hospitals," "intervention," "effectiveness," "program," and "fall prevention program." "Home care services" and "community care" were used as exclusion key words. Second, the reference list of each publication identified from the database search was searched for additional relevant studies.

Inclusion and Exclusion Criteria

Included studies met the following criteria: primary research, study of the effectiveness of fall prevention programs in hospitals, number of falls or fallers as main outcome, prospective controlled design (randomized, controlled trial or controlled trial with parallel controls), and published in English, Dutch, or French. Studies were excluded if they focused only on the effect of intermediate outcomes (such as balance and strength), if they were controlled trials with historical controls, and if they investigated the effectiveness of fall prevention programs in emergency departments or divisions for ambulatory treatment.

Critical Appraisal

The methodological qualities of the studies were assessed on the basis of 10 criteria[19] (Table 1). Two reviewers independently scored these criteria on a scale of 0 to 2, depending on whether the criterion was not met, not clearly mentioned, or not mentioned (0); partially met (1); or completely met (2). Afterwards, scoring differences of opinion were discussed with two additional coauthors until consensus was reached. The total quality score ranged from 0 (low quality) to 20 (high quality).

Data Collection, Analysis, and Synthesis

Characteristics and effectiveness of the intervention programs were extracted from the studies. The interventions were sorted according to their intervention composition (uni- and multifactorial interventions). The effectiveness of the intervention was classified per outcome (i.e., number of falls, fallers, recurrent fallers, fall-related injuries, and time

Table 1. Methodological Quality Assessment of the Studies Included in This Review

Quality Criteria Study	Clearly Defined Inclusion and Exclusion Criteria	Randomization	Comparable Treatment Groups at Entry	Identical Standard Programs for Both Groups	"Fall Incident" Clearly Defined and Staff Trained in Definition	Blinded Treatment Providers	Blinded Outcome Assessors	Blinded Patient	Identical Appraisal of Outcomes	Intention-to-Treat Analysis	Total Score (0–20)
Bischoff[22]	2	2	2	2	2	2	1	2	2	2	19
Mayo[26]	2	0	2	2	2	0	0	1	2	0	11
Donald[23]	0	1	1	2	1	0	0	0	2	2	9
Haines[24]	1	1	2	2	2	1	0	1	2	2	14
Vassallo[29]	1	0	1	2	2	0	1	0	2	2	11
Healey[25]	0	1	1	1	0	0	1	0	2	0	6
Tideiksaar[27]	1	0	0	2	1	0	0	0	1	0	5
Schwendimann[28]	2	0	1	2	2	0	0	0	2	0	9

Scores: 0 = not meeting the criterion, mentioned but unclear, or not mentioned; 1 = partially meeting the criterion; 2 = completely meeting the criterion.

to first fall). For the number of falls, the relative risk of a fall per occupied bed day (RR_{fall}), which represents the ratio of the number of falls per 100 occupied bed days in the experimental group to the corresponding number in the control group, was calculated. For the number of fallers, the relative risk of being a faller (RR_{faller}), which represents the ratio of the proportion of fallers in the experimental group to the corresponding proportion in the control group, was calculated. To pool the risk ratios for inferential analysis, a logarithmic transform of the ratios was used, and their variance was calculated using the following formula: $Var(\ln RR) = c/n_1a + d/n_ob$. For RR_{fall}, c and d are the number of occupied bed days without a fall, a and b are the number of occupied bed days with falls, and n_1 and n_0 are the total number of occupied bed days in the experimental and control groups, respectively.[20] For RR_{faller}, c and d are the number of nonfallers, a and b are the number of fallers, and n_1 and n_0 are the total number of patients in the experimental and control groups, respectively. Other outcomes were not reported sufficiently to justify pooling data. The restricted maximum likelihood method of the SAS software package's MIXED procedure[21] was used to calculate the pooled RRs. When studies used cluster (quasi-) randomization, how sensitive the pooled RRs were to an array of assumed intracluster correlation coefficients was examined.

RESULTS

Selected Studies

The key word search in Medline and Cinahl identified 108 and 50 references, respectively. On the basis of the articles' titles and abstracts, it was determined that 32 articles (31 English and 1 Dutch) were relevant for further review. The searches of Precinahl, Invert, and the Cochrane Library failed to identify additional studies. Of the 32 articles, eight met the inclusion criteria: six randomized controlled trials,[22–27] one of which was a cluster randomized, controlled trial,[25] and two were controlled trials with parallel controls in which one cluster served as the intervention and another as the comparison group.[28,29] The remaining 24 articles were excluded for the following reasons: no primary research, outcomes not measured in hospitals, no measurement of the number of falls or fallers, design failed to meet the inclusion criteria (references are available from the authors).

Methodological Quality

Results of the methodological quality assessment are shown in Table 1. In all but one study, the intervention and control groups received the same standard treatment program,[22–24,26–29] and the determination of outcomes was clearly identical.[22–26,28,29] A clear and similar definition of "fall incident" was used in five studies[22,24,26,28,29]: "involuntarily coming to rest on the ground, floor, or other lower level"[22,24,28,29] and "an unplanned touch to the floor of any part of the patient's body excluding the feet."[26] Half of the studies used an intention-to-treat analysis.[22–24,29] In three studies, intervention and control groups were comparable at entry,[22,24,26] and clearly defined inclusion and exclusion criteria[22,26,28] were used. Only one study[22] kept the condition blind to the patient and the treatment providers and used blind conditions in the case of randomization. No study completely used blind conditions for the outcome assessors.

Setting and Population

The mean age of the population for the reviewed studies varied from 69 to 85. All of these studies took place in the hospital, but most of them were conducted on long-stay geriatric care units[22] and geriatric rehabilitation units.[23,24,26,29] One study was conducted on acute and rehabilitation units,[25] and only two studies took place solely on acute units (geriatric wards[27] and internal medicine units[28]). Because there are real differences between these kinds of settings (e.g., length of stay, patient's condition), this distinction was clearly made in Tables 2 and 3.

Characteristics of the Intervention Programs

In all but one study,[22] several fall risk factors were assessed in a standardized manner (Table 2).

Unifactorial Interventions

In one study,[22] all of the participants had a greater risk of falling because of old age and extended stay in geriatric units (vitamin D deficiency and reduced musculoskeletal function). This 12-week study assessed whether altering calcium homeostasis and increasing muscle strength (by giving patients vitamin D in addition to their usual calcium carbonate dietary supplement) reduced the risk of falling.

Two other studies[26,27] also examined the effect of one intervention—an identification bracelet and a bed alarm system, respectively—on reducing falls. Patients in the intervention groups received the intervention if they scored positive on at least one risk factor (Table 2). The bracelet was intended to increase the vigilance of patients and staff to guard against falls. The bed alarm system consisted of a pressure-sensitive pad placed on top of a patient's mattress, underneath the bed sheets. When an at-risk patient sat upright, audio and visual alarms were triggered at the nursing station, alerting nurses that a patient who should not have been leaving his bed without assistance was doing so.

In a fourth study,[23] researchers examined whether flooring types (carpet vs vinyl) in the bed areas and additional exercises designed to strengthen hip flexors and ankle dorsiflexors reduced patient falls. For each group, a randomization process was performed twice: once for assignment to a floor group (carpet or vinyl) and once to determine which of the patients would receive additional exercises. Because the authors analyzed both of the interventions separately, their study was interpreted as consisting of two unifactorial intervention studies.

Multifactorial Interventions

In the four remaining studies,[24,25,28,29] fall prevention programs consisted of several interventions. Two studies[24,25] chose interventions that were suitable for addressing the identified risk factors. For example, patients with mobility or gait problems underwent an exercise program, and patients suspected of using drugs that may increase the risk for falling underwent medication review. In the first study,[24] a multidisciplinary team (medical and nursing staff, physiotherapists, occupational therapists) performed the screening and interventions, but in the second study[25] only

Table 2. Components of Falls Risk Assessment

Fall Risk Factors Study	Mobility or Gait Problems	History of Falls	Drug Use	Pathology	Foot (Wear) Problems	Mental Status or Confusion	Vision	Continence	Blood Pressure (Standing or Lying)	Bedrails/ Height/ Stability	Nurse Call System	Other
Long-stay wards (mean LOS >1.5 years)												
Bischoff[22]												
Rehabilitation wards (mean LOS 36.9 days)												
Mayo[26]		+		+				+				
Donald[23]	+		+		+	+	+	+	+			
Haines[24]	+	+	+	+	+							
Vassallo[29]	+	+	+			+	+					Hearing impairment
Rehabilitation and acute wards (mean LOS 19.7 days)												
Healey[25]	+		+		+		+		+	+	+	Blood nitrites and proteins in urine, environmental risk factors
Acute wards (mean LOS 11.7 days)												
Tideiksaar[27]	+				+					+	+	
Schwendimann[28]	+	+		+		+						Intravenous therapy or intravenous lock

LOS = length of stay.

nurses performed the interventions. Nonetheless, many of the interventions in this study included referrals to healthcare professionals of other disciplines (e.g., physiotherapist, optician). Furthermore, patients were classified as being at low or high risk for falling before risk-factor assessment, and risk-factor assessment and interventions were applied only to high-risk patients (patients admitted with a history of falls, patients who had fallen or had near misses during their current admission).

In a third multifactorial study,[28] the intervention protocol was implemented with the standard nursing care plan of all patients and directed toward modifying the hospital environment, supporting patient activities (such as assisting with transfers and toileting), and increasing staff awareness. They focused on patients identified as being at high risk of falling, as determined using the Morse Fall Scale. In addition, in-depth instructions of registered nurses and audits every other week for nurses were held in the intervention group. Although this intervention was led by nurses, healthcare professionals from other disciplines (e.g., physiotherapist, physician) were consulted if necessary. Analysis of the detailed protocol description showed that many interventions can be matched to the risk factors of the Morse Fall Scale.

Finally, a fourth multifactorial study[29] examined how weekly multidisciplinary discussions (physician, nurse, physiotherapist, occupational therapist, social worker) of patients' fall risk and a formulation of a targeted plan affect patient falls. Patients identified at high risk according to the Downton score were given an identification wristband, measures were taken to reduce the risk factors, and the environment was adapted when needed.

Effectiveness of the Intervention Programs

Number of Falls

The number of falls was measured for eight interventions,[22–25,27–29] of which six[22–25,27,28] led to fewer falls in the intervention group than in the control group. One unifactorial[22] and two multifactorial studies[24,25] showed a significant reduction in falls of 49% (after 12 weeks), 30% (after 45 days), and 41% (effect time not available), respectively. In another study,[29] the intervention group had significantly more falls per occupied bed day, although for RR_{fall}, the difference between the intervention and control groups was not significant (95% CI = 0.81–1.41). Pooling data was possible only in the four multifactorial studies that stated the total number of occupied bed days in the intervention and control groups.[24,25,28,29] The pooled RR_{fall} of 0.74 (95% CI = 0.58–0.96) indicated a significant effect in the intervention group, although when an intraclass correlation of 0.01 was assumed in the clustered randomization study,[25] the relationship was not significant anymore (RR_{fall} 0.82, 95% CI = 0.65–1.03). Assuming a higher intraclass correlation and assuming the existence of additional intraclass correlation in the quasi-experimental studies,[28,29] which could also be considered as having clustered group allocation, would have further decreased the statistical significance of this finding. The mixed model including all studies could not be simulated, because it did not converge.

Table 3. Summary of the Selected Studies

								Results			
Study	Design	Study Period	Sample Size, N	Mean Age	Mean Length of Stay, Days	Intervention		Falls	RR_{fall} (95% CI)	Fallers (%)	RR_{faller} (95% CI)
Long-stay wards (mean LOS >1.5 years)											
Bischoff[22]	RCT	12 weeks	122	85.2	>466.9	Unifactorial	Ca plus vit D3	(per person/wk) C: 0.08; I: 0.03*	CNP	C: 30.0%; I: 22.6% NS	0.75 (0.41–1.37)
Rehabilitation wards (mean LOS 36.9 days)											
Mayo[26]	RCT	1 year	134	71.9	71.2	Unifactorial	ID	NA	CNP	C: 30.4%; I: 41.5% NS	1.37 (0.86–2.16)
Donald[23] (exercise)	RCT	9 months	54	82.9	29.6	Unifactorial	EX	(per person/m) C: 0.03; I: 0.02 NS	CNP	C: 25.0%; I: 6.7% Stat sign NA	0.27 (0.06–1.21)
Donald[23] (flooring type)	RCT	9 months	54	82.8	29.2	Unifactorial	Carpet (vs vinyl)	(per person/m) C: 0.00; I: 0.04 NS	CNP	C: 3.8%; I: 25.0% Stat sign NA	6.58 (0.86–50.48)
Haines[24]	RCT	10 months	626	80.0	29.5	Multifactorial	RA, TI (AC, EX, ED, HP)	(per 100 obd) C: 1.61; I: 1.12 after 45 days*	0.70 (0.54–0.89)	C: 22.5%; I: 17,4% Stat sign NA	0.77 (0.56–1.06)
Vassallo[29]	CT	1 year	825	81.7	25.0	Multifactorial	RA, TI (ID, EX, ED, MR, ER)	(per 100 obd) C: 1.15; I: 1.23*	1.07 (0.81–1.41)	C: 20.2%; I: 14.2% NS†	0.70 (0.50–0.98)
Rehabilitation and acute wards (mean LOS 19.7 days)											
Healey[25]	RCT	12 months	1,654	81.3	19.7	Multifactorial	RA, TI (EX, ED, MR, ER, ME, EC)	(per 100 obd) C: 1.92; I: 1.13*	0.59 (0.49–0.70)	NA	CNP
Acute wards (mean LOS 11.7 days)											
Tideiksaar[27]	RCT	9 months	70	84.0	NA	Unifactorial	BAS	(per person/m) C: 0.04; I: 0.02 NS	CNP	NA	CNP
Schwendimann[28]	CT	4 months	409	70.6	11.7	Multifactorial	RA, TI (EX, ED, ER, AN)	(per 100 obd) C: 1.57; I: 1.15 NS	0.73 (0.47–1.14)	C: 11.8%; I: 12.6% NS	1.07 (0.63–1.80)

* Statistically significant difference ($P<.05$) between intervention and control groups.

† These results did not remain significant after controlling for differing length of stay.

AC = falls risk Alert Card with information brochure; AN = assistance by a nurse for activities of daily living; BAS = bed alarm system; C = control group; CI = confidence interval; CNP = calculation not possible; CT = controlled trial; EC = eyesight correction; ED = education; ER = environmental review; EX = exercise or physiotherapy; HP = hip protector; I = intervention group; ID = identification bracelet; LOS = length of stay; ME = medical examination; MR = medication review; NA = not available; NS = no statistically significant difference between intervention and control groups; obd = occupied bed days; RA = risk assessment; RCT = randomized, controlled trial; RR_{fall} = relative risk of a fall (ratio of the percentage of falls per bed day in the experimental group to the corresponding percentage in the control group); RR_{faller} = relative risk of being a faller (ratio of the proportion of fallers in the experimental group to the corresponding proportion in the control group); Stat sign = statistical significance; TI = targeted intervention; UNI = unifactorial intervention; Ca = calcium carbonate; vit D3 = vitamin D3.

Number of Fallers

The number of fallers was measured in seven intervention studies.[22–24,26,28,29] In two unifactorial[22,23] and two multifactorial[24,29] studies, the intervention group had fewer fallers than the control group, but the difference failed to reach significance. The pooled RR_{faller} was 0.87 but was not significant (95% CI = 0.70–1.08).

Number of Recurrent Fallers

In two studies[28,29] the number of recurrent fallers was assessed. Only one study[28] gave exact data and reported significantly fewer multiple fallers in the intervention group.

Number of Physical Injuries and Time to First Fall

Two studies[24,28] measured the number of fall-related injuries. One[24] found a reduction of 28% in the intervention group, but this was not significant. Furthermore, no differences between intervention and control groups were found for the number of fallers with fall-related injuries,[29] the severity of fall-related injuries,[26] and time to first fall,[26,28] although one study[28] found a significantly longer time to first fall in the intervention group after 4 days of hospitalization.

Adverse Effects of the Intervention Programs

Four studies considered adverse effects of their fall prevention program.[22–24,27] In the study that tested vitamin D in addition to the usual calcium carbonate dietary supplement,[22] two subjects in the calcium plus vitamin D group (0.03%) reported increased constipation, but this did not lead to discontinuation of treatment. In the study that examined the flooring types in the bed areas,[23] carpeting was associated with a smaller improvement in dependency than vinyl flooring, but this difference was not significant. The other two studies mentioned possible adverse effects (e.g., violation of privacy,[24] bodily harm[27]), but these were not found in the intervention group. No study demonstrated a significantly greater number of falls or (recurrent) fallers, except for one study (mentioned above).[29]

DISCUSSION

For unifactorial[23,26,27] intervention studies, the number of falls were not reduced, except for one study[22] that used a unifactorial pharmacological approach (calcium plus vitamin D_3) and found a significant reduction of 49% in the intervention group. Furthermore, two multifactorial[24,25] intervention studies found fewer falls in the intervention group, 30% and 41% fewer, respectively. The pooled RR_{fall} for the four multifactorial studies became nonsignificant after assuming the existence of an intraclass correlation in at least one study that used clustered group allocation (RR_{fall} = 0.82; 95% CI = 0.65–1.03). No study demonstrated a significant reduction in the number of fallers in the intervention group, whether they were pooled or not.

Only three studies demonstrated a significant reduction in number of falls in the intervention group. One tested a unifactorial pharmacological approach in a sample of 122 older women living in a subacute long-stay geriatric care unit. This target group was at risk of vitamin D deficiency and thus poorer musculoskeletal function that increased their risk for falling.[22] Accordingly, the administration of a calcium supplement plus vitamin D was clearly targeted, which can explain the 49% reduction of fall incidents. Similar purposeful actions focusing on high-risk factors of the patients were absent in the other unifactorial studies.[23,26,27] In these studies, at-risk patients were identified, but only general, nontargeted interventions were applied. This shortcoming was avoided in the four multifactorial intervention studies.[24,25,28,29] Only two of these studies[24,25] produced fewer falls in the intervention group. One of the other studies[29] reported a significantly greater number of falls per occupied bed day in the intervention group, but a risk calculation found no significant difference between the intervention and control group. The lack of clear benefit could be related to the fact that intervention and control groups were in close proximity, resulting in a possible spillover effect. The other study[28] tested a fall prevention program in an acute setting and demonstrated fewer falls, although not significantly so. In view of this, next to the targeted focus, other aspects, such as the kind of setting, might play a fundamental role in the effectiveness of fall prevention programs in hospitals too (see below).

No intervention (e.g., primary prevention or preventing a first fall) showed a significant reduction in number of fallers. First, the fact that no intervention showed an effect in the acute phase of hospitalization might explain the lack of evidence for primary prevention. Effects were noted only for patients admitted for longer periods of time, namely in studies conducted in long-stay geriatric or rehabilitation settings. Precisely in these settings, like in residential care homes and community care, the likely delayed benefit from interventions such as calcium plus vitamin D_3, physiotherapy, and medical review can be better achieved than in an acute setting. One study[24] showed this delayed effect by calculating Nelson-Aalen cumulative hazard estimates in the control and intervention groups, showing no difference between the groups until approximately Day 45. At this time, the fall rate in the control group increased marginally and the rate in the intervention group suddenly decreased. Another study[28] observed a significant reduction only for time to first fall in the intervention group after 4 days of hospitalization. This "time" issue raises the hypothesis that, in the acute care setting, individually targeted fall prevention interventions may have no clear or durable benefit unless they are started before the incident hospitalization. If so, acute hospital settings might benefit from a close collaboration with residential setting and community care, because well-done data transmission could save unnecessary duplication of fall risk assessments and facilitate continuation of ongoing interventions. In addition, other approaches need to be tested in the acute setting to prevent falls. For example, a recent study showed that there were no inpatient falls after the introduction of volunteers to "sit" with patients identified as being at high risk of falling.[30]

Second, some studies[24,28,29] used risk-screening instruments with limited diagnostic power (e.g., not always categorizing people correctly as low or high risk), which may have diluted any efforts to prevent a first fall by poorly targeting people for inclusion in fall intervention programs. Indeed, no screening tools that have good diagnostic properties have been reported in the literature for fall risk in hospital inpatients.[31] Therefore, it may be better to focus on patients who have already fallen (e.g., ensuring that people who fall in hospitals receive a proper post-fall assessment) or to examine common reversible fall risk factors for all admitted patients.

Indeed, although a clear pooled effect of any outcome could not be demonstrated, the in-depth analysis of the individual studies suggested that fall prevention programs should identify a patient's most important fall risk factors in order to be effective. A recent review[31] identified factors that significantly predict falls in hospitals and are similar to those used in the studies included in this review (Table 2): gait instability, agitated confusion, urinary incontinence, fall history, and prescription of "culprit" drugs (especially sedative/hypnotics). Because falling is a complex and multifactorial phenomenon,[32] the chance of a beneficial effect increases as interventions target more risk factors. Nonetheless, a good effect can be achieved with a unifactorial (pharmacological) intervention.[22] Interventions must also involve healthcare workers from other disciplines. In this respect, nurses can play a central role.[25,28]

Since the completion of this review, a similar meta-analysis[33] has been published with broader inclusion criteria for design and with a focus on hospitals and care homes. For multifaceted interventions in the hospital, the authors found a significant pooled reduction for the number of falls, even after adjustment for clustering, but not for the number of fallers ($RR_{fall} = 0.82$, 95% CI = 0.68–0.99; $RR_{faller} = 0.95$, 95% CI = 0.71–1.27). Because their meta-analysis included more studies, this confirms the assumption that the failure of the current review to prove a significant pooled effect of RR_{fall} may be due to a lack in the number of (comparable) studies. Nevertheless, the poor methodological quality of the additionally included studies also needs to be taken into account.[33] For unifactorial interventions in hospitals, they found no evidence.[33] However, they included the unifactorial pharmacological study[22] in the care home analysis, although this study took place in the hospital, but on "long stay" geriatric wards. Consequently, there is no evidence that this intervention (calcium plus vitamin D) is applicable to hospital units with a length of stay shorter than 12 weeks. Furthermore, the explicit focus of the current review on fall prevention programs in hospitals allowed a more in-depth analysis to be made, which is key to gaining an insight into the underlying principles of the effectiveness of these programs.

This meta-analysis raises some methodological issues. First, research was restricted to randomized, controlled trials and controlled trials with parallel controls. Such a selection could exclude studies of lower methodological quality that assessed useful interventions. However, this selection has the advantage that the analysis is restricted to high-quality studies. Still, Table 1 shows that the quality of most of the studies included in the analysis is low. Excluding the pharmacological intervention study,[22] the mean total quality score was 9.3 out of a possible 20. No study, except the pharmacological one,[22] could completely keep the patients, hospital staff, and outcome assessors blind to the study conditions because of the nature of the interventions used. Perhaps a better measure is needed to assess the methodological quality of complex intervention studies like these. Second, the components of the multifactorial interventions as well as the methods of falls risk assessment varied greatly, so that the pooled results should be carefully interpreted.

In conclusion, this meta-analysis found no conclusive evidence that hospital fall prevention programs can reduce the number of falls or fallers. However, more studies are needed to confirm the tendency observed in the analysis of individual studies that targeting a patient's most important risk factors for falls actively helps in reducing the number of falls. These interventions seem to be useful only on long-stay care units.

On the assumption that future single-center studies would have similar effect sizes as the studies in this meta-analysis, how large the sample size should be to find a significant result with a certainty of 80% ($\alpha = 0.05$) was calculated. Detecting an effect of fall prevention strategies on the number of falls would require a sample of 23,988 bed days (calculation based on the pooled relative risk of 0.74). Detecting an effect of fall prevention strategies on the number of fallers would require a sample of 6,156 patients (based on the pooled relative risk of 0.87). These are minimal numbers, because an intraclass correlation of zero was assumed for clustered-sample studies.

Further research is also needed on primary hospital fall prevention programs (in which both the number of fallers and recurrent fallers must be counted), on fall prevention in an "acute" setting, on the fall reduction effect of the separate components of multifactorial fall prevention programs, and on cost-effectiveness of fall prevention programs.

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