Risk factors for falls among hospitalized medical patients – A systematic review and meta-analysis

Jeannelle Heinzmann MB , Michael L. Rossen MMed , Orestis Efthimiou PhD , Christine Baumgartner MDMSc , Maria M. Wertli MDPhD , Nicolas Rodondi MDMAS , Carole E. Aubert MDMSc , Fabian D. Liechti MDPhD

PII: S0003-9993(24)01077-3
DOI: https://doi.org/10.1016/j.apmr.2024.06.015
Reference: YAPMR 59164

To appear in: *Archives of Physical Medicine and Rehabilitation*

Received date: 6 October 2023
Revised date: 3 June 2024
Accepted date: 25 June 2024

Please cite this article as: Jeannelle Heinzmann MB , Michael L. Rossen MMed , Orestis Efthimiou PhD , Christine Baumgartner MDMSc , Maria M. Wertli MDPhD , Nicolas Rodondi MDMAS , Carole E. Aubert MDMSc , Fabian D. Liechti MDPhD , Risk factors for falls among hospitalized medical patients – A systematic review and meta-analysis, *Archives of Physical Medicine and Rehabilitation* (2024), doi: https://doi.org/10.1016/j.apmr.2024.06.015

Risk factors for falls among hospitalized medical patients – A systematic review and meta-analysis

Jeannelle Heinzmann[1¶], MB; Michael L. Rossen[1, 2¶], MMed; Orestis Efthimiou[2, 3], PhD; Christine Baumgartner[1], MD, MSc; Maria M. Wertli[1, 4], MD, PhD; Nicolas Rodondi[1, 2], MD, MAS; Carole E. Aubert[1, 2&], MD, MSc; Fabian D. Liechti[1&*] MD, PhD

[1] Department of General Internal Medicine, Inselspital, Bern University Hospital, University of Bern, Bern, Switzerland

[2] Institute of Primary Health Care (BIHAM), University of Bern, Bern, Switzerland

[3] Institute of Social and Preventive Medicine (ISPM), University of Bern, Bern, Switzerland

[4] Department of Internal Medicine, Kantonsspital Baden, Baden, Switzerland

¶ These authors contributed equally to this work (shared first co-authorship).

& These authors contributed equally to this work (shared last co-authorship).

This material has not been presented anywhere else.

* **Corresponding author:** Fabian D. Liechti, Department of General Internal Medicine, Inselspital, Bern University Hospital, University of Bern, Freiburgstrasse, 3010 Bern, Switzerland, fabian.liechti@insel.ch, Telephone number: +41 31 632 21 11

Funders: FDL received grants from the Swiss National Science Foundation (grant number: P500PM_206639), the Swiss Society of General Internal Medicine (SGAIM) Foundation, Bern, Switzerland (grant number: not applicable), and the 'Fondation Sana', Bern,

Switzerland (grant number: GF 2021-0048). CEA received grants from the Swiss National Science Foundation (grant number: PZ00P3_201672). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Contributors: The authors wish to thank Doris Kopp-Heim from the Public Health & Primary Care Library, University of Bern, Bern, Switzerland, for developing and updating our search strategies.

Disclosure: Dr. Orestis Efthimiou has a financial relationship with Biogen pharmaceuticals, outside the submitted work. The other authors have nothing to disclose.

Registration: PROSPERO, CRD42022315096

Objective: To identify and quantify risk factors for in-hospital falls in medical patients.

Data Sources: Six databases (MEDLINE, Embase, Cochrane Database of Systematic Reviews, Cochrane Central Register of Controlled Trials, CINAHL, and Google Scholar) were systematically screened until April 11, 2023, to identify relevant articles.

Study Selection: All titles and abstracts of the retrieved articles were independently screened by two researchers who also read the full texts of the remaining articles. Quantitative studies that assessed risk factors for falls among adult patients acutely hospitalized were included in the review. Publications that did not capture internal medicine patients or focused on other specific populations were excluded.

Data Extraction: Information on study characteristics and potential risk factors were systematically extracted. Risk of bias was assessed using the Quality in Prognosis Studies (QUIPS) tool. PRISMA and MOOSE guidelines were followed for reporting.

Data Synthesis: The main outcome was any in-hospital falls. Using a random-effects meta-analysis model, association measures for each risk factor reported in five or more studies were pooled. Separate analyses according to effect measure and studies adjusted for sex and age at least were performed.

Of 5,067 records retrieved, 119 original publications from 25 countries were included. In conclusion, 23 potential risk factors were meta-analyzed. Strong evidence with large effect sizes was found for a history of falls (OR 2.54; 95% CI 1.63– 3.96; I^2 91%), antidepressants (pooled OR 2.25; 95% confidence interval [95% CI] 1.92–2.65; I^2 0%), benzodiazepines (OR 1.97; 95% CI 1.68–2.31; I^2 0%), hypnotics–sedatives (OR 1.90; 95% CI 1.53–2.36; I^2 46%), and antipsychotics (OR 1.61; 95% CI 1.33–1.95; I^2 0%). Furthermore, evidence of associations with male sex (OR 1.22, 95% CI 0.99–1.50, I^2 65%) and age (OR 1.17, 95% CI 1.02–1.35, I^2 72%) were found, but effect sizes were small.

Conclusions: The comprehensive list of risk factors, which specifies the strength of evidence and effect sizes, could assist in the prioritization of preventive measures and interventions.

Keywords: Accidental Falls; Hospital Medicine; Health Care Quality; General Internal Medicine; Patient Safety; Adult; Aged; Physiologic Effects of Drugs; Central Nervous System Depressants.

List of abbreviations

ATC, World Health Organization's Anatomical Therapeutic Chemical Classification

QUIPS, Quality in Prognosis Studies tool

Patients are particularly vulnerable during hospitalization, with an increased risk for – potentially preventable – falls.[1] Fall rates per hospitalization day reach 2–7% with about one third of patients suffering physical harm.[2-4] Injurious falls are often not well defined and seldom systematically assessed.[1, 5] Falls often cause emotional distress, which can lead to immobility, which further increases the risk of future falls.[6] Furthermore, in-hospital falls result in extended lengths of stay and higher costs.[7]

Multidomain interventions have been demonstrated to be more effective than single interventions in reducing fall rates.[8, 9] However, implementing such interventions is challenging and requires significant resources due to the complexity of prevention programs and lack of evidence on the most effective interventions.[10] The use of screening tools to identify individuals at risk in hospitals is no longer recommended due to lack of demonstrated effectiveness; therefore, they should be replaced by multifactorial risk assessments.[11] Most guidelines on fall prevention in hospitals recommend to identify patients at risk of fall through medical history alone. This should include questions on fall history, fear of falling, and gait and balance difficulties.[11, 12] However, the relative importance of other, potentially modifiable, risk factors is not known or has been described as controversial, e.g. for hyponatremia, sedating medication, urinary incontinence, cognitive impairment, or age *per se*.[11, 13-17] Identifying which factors mostly contribute to the risk of falls could help making better use of available resources by focusing on fall-preventing interventions for those at highest risk.

Although multiple risk factors were identified, there is currently no evidence available on their relative importance.[15, 18] Furthermore, no recent meta-analysis has employed an iterative process to include as many potential risk factors as possible for in-hospital falls and quantify their importance. This systematic review und meta-analysis thus aimed to identify and quantify the risk factors for in-hospital falls in adults hospitalized in acute medical wards. The overarching goal was to provide clinicians and policymakers with a list of quantified risk factors to assist in the prioritization of preventive measures.

Methods

This systematic review and meta-analysis was conducted following the recommendations of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Statement (PRISMA) and Meta-analyses Of Observational Studies in Epidemiology (MOOSE) checklist.[19, 20] The study protocol was pre-registered in the International Prospective Register of Systematic Reviews (PROSPERO).

Literature search

A comprehensive literature search was conducted in MEDLINE (via Ovid), Embase (via Elsevier), Cochrane Database of Systematic Reviews (via Wiley), Cochrane Central Register of Controlled Trials (via Wiley), CINAHL (via EBSCOhost) and Google Scholar, from inception until April 11, 2023, with the help of an experienced medical information specialist. The full search strategies are available in the supplemental file (eTable 1 in the Supplement).

Selection criteria

Quantitative studies in English that assessed injurious and non-injurious falls among adult patients hospitalized on acute medical wards throughout the world (defined as including at least [general] internal medicine or acute geriatric wards, to analyze as many studies as possible with a substantial proportion of medical hospitalized patients) were included. “Falls” and “injurious falls” were defined according to the definitions of the included studies’ authors. Publications focusing on repetitive falls or specific populations such as those in cardiology, stroke units, intensive care units were excluded. Reviews and meta-analyses were excluded after identifying the original studies in their references without doing systematic citation chaining on original articles or contacting the authors due to the high

number of articles included. If multiple publications on the same or overlapping study population were available, information on risk factors was extracted from the publication with the largest sample or most recent publication.

Two researchers independently screened all the titles and abstracts using EndNote (version 20.4.1, Clarivate Analytics, Philadelphia, PA, USA) in accordance with the GRADE framework.[21-23] Both reviewers then independently assessed the full texts. Any disagreements were resolved by consensus or through discussion with a senior author.

Data extraction

From all included studies, data was collected by one author. A second author validated all data entries; disagreements were discussed and resolved. The modified Checklist for Critical Appraisal and Data Extraction for Systematic Reviews of prognostic factor studies (CHARMS-PF) was used as guidance.[21, 24] Data items extracted included study characteristics (i.e. authors, years of publication, study design), the statistical model used, study setting, study population, ward type, and relevant exclusion criteria, and the risk factors as defined by the studies' authors with its effect estimates. For publications presenting both univariable and multivariable analyses, only the latter was included to better account for possible confounding. If more than one model was presented, only the model deemed most appropriate to our research question was kept. If a study reported coefficients for a risk factor after adjusting for different sets of covariates, the maximally adjusted estimate was kept in the meta-analysis.

Quality assessment

Two researchers independently assessed the study quality using the Quality in Prognosis Studies (QUIPS) tool.[25] Any disagreements were resolved by consensus or through discussion with a senior author. We assessed and classified each domain's risk of bias into the categories of low, moderate, or high risk of bias using the prompting items provided within the tool. Key indicators of a high risk of bias were: 1) the non-random selection of controls from the underlying cohort in case-control studies; 2) high losses to follow-up in cohort studies; 3) inadequately low numbers of events (< 10 cases per parameter used in multivariable models); and 4) several items per domain being rated as a moderate risk. Examples of a moderate risk of bias were: 1) a lack of any detailed description of cohorts, methods, or results; 2) a borderline number of events (~10 cases per parameter); and 3) not using conditional logistic regression in matched case-control studies.

Categorization of risk factors

Risk factors were categorized using an iterative process. First, risk factors were categorized into one of 44 predefined domains, e.g. age, sex, or comorbidities (see eTable 3 in the Supplement) by two authors working together. Second, the two authors collaborated to refine the categorization process, taking into account the heterogeneity of the studies' definitions and reporting methods. For instance, hemoglobin (a continuous variable) and anemia (a discrete variable) were categorized as separate risk factors. For medication use, definitions from the World Health Organization's Anatomical Therapeutic Chemical (ATC) Classification were employed whenever feasible.[26] Only one representative potential risk factor from each cohort was retained even when multiple were reported (e.g. age was selected as a continuous or a categorical variable). To investigate the effect of "delirium" and "dementia" separately, these diagnoses were extracted whenever possible, in contrast to the more heterogeneous definition of "cognitive impairment". A third author approved the final list of risk factors which is presented in eTable 3 in the Supplement.

Data analysis

We performed the following analyses: 1) studies with low or moderate risk of bias and adjustment for at least sex and age (primary analysis); 2) studies with low or moderate risk of bias, independent of adjustments (secondary analysis); 3) studies independent of risk of bias assessment and independent of adjustments (sensitivity analysis); 4) studies with adjustment for at least sex and age, independent of risk of bias assessment (sensitivity analysis); 5) studies without age-related exclusion criteria (sensitivity analysis); 6) studies including older patients (aged 60 years old or more or in a geriatric unit) only (sensitivity analysis). For all these analyses separate meta-analyses were planned per outcome (falls, injurious falls) and per effect measure (OR, risk ratio [RR], hazard ratio [HR], incidence rate ratio [IRR]) when reported in five or more studies. A random-effects meta-analysis model was used to pool the association measures for each risk factor by including their published effect measures and calculating standard errors from CIs, when necessary.[27, 28] The restricted maximum likelihood method was used to calculate heterogeneity variance τ^2. Between-study heterogeneity was assessed using I^2 and by calculating 95% prediction intervals (PIs) with Knapp-Hartung adjustments.[29-31] To assess the quality of evidence of pooled studies with low–moderate risk of bias an adapted version of the Grading of Recommendations, Assessment, Development, and Evaluations (GRADE) framework was used. Four levels of evidence (very low, low, moderate, high) were used with starting at "very low" quality of evidence. Key considerations to increase the levels of evidence were adjustment for age and sex, precision (95% CIs excludes null effect), consistency (95% PIs excludes null effect), and lack of publication bias (no Funnel plot asymmetry and Egger's *P* value ≥ 0.05) We checked for small-study effects and publication bias by visually using contour-adjusted funnel plots, and performed an Egger's test when there were 10 or more studies available.[32] All analyses were performed using R Statistical Software (version 4.2.1; R Core Team 2021; packages referenced in eTable 4 in the Supplement).[31, 33]

Results

We identified 5,067 unique records, of which 119 studies from 25 countries were included (Figure 1, full list of references and description of the study characteristics in eTables 5 and 6 in the Supplement). Of the 119 studies, 62 were rated as high risk of bias, among which 59 with the outcome "falls" only, 1 with the outcome "injurious falls" only, and 2 with both outcomes (eTables 7 and 8 in the Supplement). The number of risk factors available for primary, secondary and sensitivity analyses is presented in eTable 9 in the Supplement.

Risk estimates

The final analysis included 13 risk factors obtained from studies with low-to-moderate overall risks of bias and reporting adjusted effect measures (Figure 2, eTable 10 in the Supplement). When also studies that reported crude estimates were included in the analysis, a total of 23 potential risk factors were identified (Fig 3, eTable 11 in the Supplement). For other risk factors (impaired vision, cerebrovascular disease, kidney disease, musculoskeletal disease, number of diagnoses, number of medications, polypharmacy, cancer, antiarrhythmics, antihypertensives) the number of studies was too small to pool effect sizes or perform meta-analyses. Forrest plots and funnel plots with Egger's *P values* to evaluate small-study effects and publication bias are shown in eFigures 1-110 and eTable 12 in the Supplement. The level of evidence for the risk factors is presented in eTable 13.

Demographic factors

We found strong evidence of an association between falls and age (adjusted OR [aOR] = 1.17; 95% CI 1.02–1.35 for a 10-year increase, PI 0.74–1.85); between-study heterogeneity was largely attributed

to a single study that demonstrated a negative association.[34] When including crude effect measures, age could be analyzed as a continuous variable (a 10-year increase in age, OR 1.23; 95% CI 1.06–1.42; PI 0.66–2.27) or as a dichotomized variable (advanced age [above 65–79 years], OR 2.06; 95% CI 1.82–2.32; PI 0.99–4.30; low heterogeneity).

We found strong evidence of a relatively small association with male sex (aOR 1.22; 95% CI 0.99–1.50; PI 0.64–2.33; including crude effect estimates, OR 1.29; 95% CI 1.08–1.55; PI 0.70–2.38).

Comorbidities

The analysis of comorbidities was only possible when including crude effect estimates. Parkinson's disease was the risk factor with the highest pooled effect estimate, moreover between-study heterogeneity was low (OR 3.67; 95% CI 2.37–5.69; PI 0.15–90.26). Cerebrovascular diseases showed a smaller effect estimate with low heterogeneity (OR 1.62; 95% CI 1.19–2.22; PI 1.14–2.32). We found an association between diabetes mellitus (OR 1.61; 95% CI 1.16–2.24; PI 0.62–4.21) and dementia (OR 2.15; 95% CI 1.40–3.29; PI 0.12–37.17) with some heterogeneity. Hyponatremia had a strong association and low heterogeneity (OR 1.56; 95% CI 1.38–1.77; PI 1.31–1.86; I^2 0%) although the limited number of studies precluded creation of funnel plots. No association was found between recent surgery and falls, with substantial heterogeneity (OR 1.04; 95% CI 0.44–2.50; PI 0.11–10.01).

Medication

We found strong evidence of associations with antidepressants (aOR 2.25; 95% CI 1.92–2.65; PI 1.68–3.03), benzodiazepines (aOR 1.97; 95% CI 1.68–2.31; PI 1.54–2.52), hypnotics–sedatives (aOR 1.90; 95% CI 1.53–2.36; PI 1.42–2.54) and antipsychotics (aOR 1.61; 95% CI 1.33–1.95; PI 1.27–2.05), with similar results after adding crude effect estimates. Heterogeneity was low

(antidepressants, benzodiazepines, antipsychotics) or moderate (hypnotics-sedatives). For non-specified psychotropics (aOR 2.36, 95% CI 1.21–4.61, PI 0.45–12.51, Egger's test *P* = 0.0099) and opioids (aOR 1.93, 95% CI 0.91–4.08, PI 0.55–6.73) we found moderate evidence for an association.

The level of evidence for an association with anticonvulsants (OR 2.76; 95% CI 1.61–4.74; PI 0.59–12.91) was low due to limited number of adjusted studies and moderate heterogeneity. No association was found between diuretics and falls (aOR 0.96; 95% CI 0.52–1.77; PI 0.24–3.89).

Functional status

A history of falls had the largest pooled OR (aOR 2.54; 95% CI 1.64–3.93; PI 0.54–11.82; including crude effect estimates OR 2.50; 95% CI 1.90–3.28; PI 0.83–7.55); however, substantial between-study heterogeneity was observed, largely due to the influence of a single study demonstrating a markedly large effect estimate (OR 8.1; 95% CI 6.1–10.8).[35]

Evidence for an association of cognitive impairment (aOR 1.66; 95% CI 1.28–2.16; PI 0.97–2.86; Egger's *P* = 0.0024) and mobility disorders (aOR 1.89; 95% CI 1.11–3.23; PI 0.16–22.82) was only moderate due to heterogeneity and possible publication bias.

Sensitivity analyses

When including studies with a high risk of bias and adjustments for sex and age, at least, 23 potential risk factors for the outcome of "falls" reported in five or more cohorts were identified. CIs for pooled effect estimates were wider and estimates of between-study heterogeneity were larger, but the direction of effects remained stable without identifying any additional relevant risk factors (eTables 14 and 15, eFigures 111 and 112 in the Supplement).

Some studies set age limitations as an inclusion criterion or split their cohorts (i.e., older vs. younger patients). When excluding those studies, a history of falls, the use of hypnotics–sedatives and cognitive impairment were found to be associated with falls (eTables 16 and 17, eFigures 113 and 114 in the Supplement). We also found evidence of an age effect, albeit with greater heterogeneity (aOR 1.21; 95% CI 1.09–1.34; PI 0.77–1.90). Advanced age [above 65–79 years] was also found to be associated with falls when including crude effect estimates (OR 2.08; 95% CI 1.88–2.31; PI 1.67–2.61).

When solely synthesizing studies that excluded participants younger than 60–75 years old, the use of antipsychotics (OR 1.71; 95% CI 1.28–2.28; PI 1.21–2.42), benzodiazepines (OR 2.10; 95% CI 1.68–2.62; PI 1.44–3.05), and non-specified psychotropics (OR 2.56; 95% CI 1.93–3.38; PI 1.67–3.91) demonstrated strong associations with falls and low heterogeneity (eTable 18 and eFigure 115 in the Supplement).

Discussion

In this systematic review and meta-analysis of 119 studies, strong evidence was found for associations and large effect sizes between falls and advanced age [above 65–79 years], some comorbidities (Parkinson's disease, diabetes mellitus, hyponatremia), the use of specific medications (antidepressants, benzodiazepines, hypnotics–sedatives, antipsychotics, non-specified psychotropics, anticonvulsants), and functional limitations (a history of falls, mobility disorders, cognitive impairment). There was strong evidence of associations, with small effect sizes, for increasing age (as a continuous variable) and male sex. Some risk factors reported elsewhere (e.g., sarcopenia, orthostatic hypotension) were not included in our study because there were not enough original studies available

to adequately perform meta-analysis. A previous meta-analysis identified history of falls, Parkinson's disease, use of walking aids, and gait problems (odds ratios 2–3) as risk factors for falls in older adults in the community a – factors that were also identified in the current analysis.[15]

We identified several comorbidities associated with fall risk. While some of these are markers of impaired health, others may have a causal role. For example, hyponatremia is associated with gait disturbance and cognitive impairment and has previously been described as risk factor for falls.[13] Postural instability and gait disorders are characteristic of Parkinson's disease, however, not all patients with Parkinson's disease have the same risk of falling.[36] Reasons for diabetes mellitus being a risk factor for falls may include autonomous neuropathy with consecutive hypotension or hypoglycemia, especially in patients with advanced age. In contrast, patients with recent surgery may not fall if they are not mobilized. These observations implicate that comorbidities need to be considered when evaluating patients to reduce the risk of falls.

We did not find any fall-increasing risk for diuretics but identified several medication groups classified in the ATC chapter "Nervous System" as risk factors, confirming the results of previous systematic reviews or meta-analyses.[17, 37, 38] Medication reviews and deprescribing should be part of fall prevention interventions to reduce potentially inappropriate medications.[11, 39] It should be noted, however, that associations between exposure and outcome may not be causal due to confounding. For example, effect of anticonvulsants on falls cannot be properly interpreted without controlling for epilepsy. Also, the fall risk of some medications, e.g., antidepressants or diuretics, may differ by mechanism or dose, which was beyond the scope of the current meta-analysis.

Among functional limitations and geriatric syndromes, a previous analysis identified gait instability, confusion, urinary incontinence, and a history of falls as risk factors.[17] A more recent meta-analysis also reported mental and behavioral disorders as risk factors (conference abstract not indicating CIs).[14]

These results are in line with our findings identifying a history of falls, cognitive impairment, mobility disorders and incontinence as risk factors. Pain could not be included in the current meta-analysis, because not enough studies reported it as a risk factor, despite being mentioned as a strong risk factor for in-hospital falls in the above meta-analysis.[14]

Strengths and study limitations

This study has several strengths: Risk of bias was assessed and all potential risk factors for in-hospital falls were appraised, whereas previous systematic reviews did not pool effect estimates or were restricted to a much smaller set of studies.[15-17] To increase the generalizability of the findings, all studies on internal medicine and geriatric wards were considered. We reported the identified risk factors in terms of their pooled effect size and certainty (prediction, heterogeneity) to rank them.

The analysis also has some limitations. First, definitions of potential risk factors were not predefined but extracted from the literature using an iterative process to establish a comprehensive review of risk factors and reduce selection bias. Assigning risk factors to an analyzable group required us to make assumptions (e.g., some medication classifications did not match the ATC classification), which could have led to misclassification and increased heterogeneity.[40] However, an iterative process was used to collect as many potential risk factors as possible to establish a comprehensive review. Second, the high risk of confounding in observational studies was addressed by restricting the analyses to a subset of studies that adjusted for at least a minimum set of potential confounders (age and sex) as a marker for adjustment for other variables.[41] Furthermore, a risk-of-bias rating was used to assess whether the exposure was measured before the outcome, which was usually the case.[42] Third, published effect sizes were used for comparison, without considering individual patient data, which may have led to reporting biases, e.g., when studies only reported statistically significant associations. Using pre-calculated effect sizes also entailed that Peter's test could not be performed, and Egger's *P* values were

presented instead where applicable. Fourth, environmental factors were not included because of a lack of sufficiently standardized definitions, illustrating the difficulty of systematically assessing environmental factors in quantitative studies. This lack of inclusion contradicts the required evaluation of environmental modifications as recommended in guidelines to reduce falls.[12] Finally, due to limitations in the search (i.e., English language only, no citation chaining) not all studies may have been identified; however, a large number of studies from all geographic regions and covering a 37 year time span were retrieved, and funnel plots were presented to identify potential publication bias.

Clinical implications

The findings of this systematic review and meta-analysis support current guidelines, which recommend assessing fall history, gait, balance and mobility at hospital admission.[11, 12, 43, 44] The identification of patients with other important risk factors such as nervous system medications, Parkinson's disease, hyponatremia and cognitive impairment could help refine fall risk assessment.

Altogether, these findings could help identify those patients at the highest risk of a fall and direct appropriate preventive measures to those most likely to benefit from them. Such interventions should include treatment of underlying conditions that increase the risk of falls, medication review, patient education, physical activity, the use of walking aids, and physiotherapy.[12, 45] Future studies should also identify and define environmental factors – elements which could not be quantified in this meta-analysis.

Conclusions

In conclusion, a wide range of risk factors for in-hospital falls were identified and, most importantly, ordered according to their relative importance, based on the strength of evidence and effect size of each individual risk factor. Strong evidence with a large effect size was found for a history of falls, antidepressants, benzodiazepines, hypnotics–sedatives, and antipsychotics. Associations with male sex and age were also found, but effect sizes were small. These findings can help to better assess the risk of in-hospital falls in individual patients, which is needed to individualize patient care and target fall-preventing measures to those at highest risk. It may also contribute to the development of innovative and evidence-based clinical prediction models.

Data availability

The datasets generated during and/or analyzed during the current study are available in the GitHub repository. (https://github.com/)

References

1. Growdon ME, Shorr RI, Inouye SK. The Tension Between Promoting Mobility and Preventing Falls in the Hospital. JAMA Intern Med 2017;177(6):759-60.

2. Bernet NS, Everink IH, Schols JM, Halfens RJ, Richter D, Hahn S. Hospital performance comparison of inpatient fall rates; the impact of risk adjusting for patient-related factors: a multicentre cross-sectional survey. BMC Health Serv Res 2022;22(1):225.

3. Healey F, Scobie S, Oliver D, Pryce A, Thomson R, Glampson B. Falls in English and Welsh hospitals: a national observational study based on retrospective analysis of 12 months of patient safety incident reports. Qual Saf Health Care 2008;17(6):424-30.

4. Oliver D, Healey F, Haines TP. Preventing falls and fall-related injuries in hospitals. Clin Geriatr Med 2010;26(4):645-92.

5. Schwenk M, Lauenroth A, Stock C, Moreno RR, Oster P, McHugh G et al. Definitions and methods of measuring and reporting on injurious falls in randomised controlled fall prevention trials: a systematic review. BMC Med Res Methodol 2012;12:50.

6. Mahoney JE. Immobility and falls. Clin Geriatr Med 1998;14(4):699-726.

7. Morello RT, Barker AL, Watts JJ, Haines T, Zavarsek SS, Hill KD et al. The extra resource burden of in-hospital falls: a cost of falls study. Med J Aust 2015;203(9):367.

8. Morris R, O'Riordan S. Prevention of falls in hospital. Clin Med (Lond) 2017;17(4):360-2.

9. Cameron ID, Dyer SM, Panagoda CE, Murray GR, Hill KD, Cumming RG et al. Interventions for preventing falls in older people in care facilities and hospitals. Cochrane Database Syst Rev 2018;9:CD005465.

10. Hempel S, Newberry S, Wang Z, Booth M, Shanman R, Johnsen B et al. Hospital fall prevention: a systematic review of implementation, components, adherence, and effectiveness. J Am Geriatr Soc 2013;61(4):483-94.

11. Montero-Odasso M, van der Velde N, Martin FC, Petrovic M, Tan MP, Ryg J et al. World guidelines for falls prevention and management for older adults: a global initiative. Age Ageing 2022;51(9).

12. Montero-Odasso MM, Kamkar N, Pieruccini-Faria F, Osman A, Sarquis-Adamson Y, Close J et al. Evaluation of Clinical Practice Guidelines on Fall Prevention and Management for Older Adults: A Systematic Review. JAMA Netw Open 2021;4(12):e2138911.

13. Corona G, Norello D, Parenti G, Sforza A, Maggi M, Peri A. Hyponatremia, falls and bone fractures: A systematic review and meta-analysis. Clin Endocrinol (Oxf) 2018;89(4):505-13.

14. Govoni E, Porta FL, Negro A. Evaluation of fall risk factors for among hospitalized patients: systematic review and meta-analysis: Erika Govoni. European Journal of … 2022.

15. Deandrea S, Bravi F, Turati F, Lucenteforte E, La Vecchia C, Negri E. Risk factors for falls in older people in nursing homes and hospitals. A systematic review and meta-analysis. Arch Gerontol Geriatr 2013;56(3):407-15.

16. Evans D, Hodgkinson B, Lambert L, Wood J. Falls risk factors in the hospital setting: a systematic review. Int J Nurs Pract 2001;7(1):38-45.

17. Oliver D, Daly F, Martin FC, McMurdo ME. Risk factors and risk assessment tools for falls in hospital in-patients: a systematic review. Age Ageing 2004;33(2):122-30.

18. Terroso M, Rosa N, Torres Marques A, Simoes R. Physical consequences of falls in the elderly: a literature review from 1995 to 2010. European Review of Aging and Physical Activity 2014;11:51-9.

19. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ 2021;372:n71.

20. Stroup DF, Berlin JA, Morton SC, Olkin I, Williamson GD, Rennie D et al. Meta-analysis of observational studies in epidemiology: a proposal for reporting. Meta-analysis Of Observational Studies in Epidemiology (MOOSE) group. JAMA 2000;283(15):2008-12.

21. Riley RD, Moons KGM, Snell KIE, Ensor J, Hooft L, Altman DG et al. A guide to systematic review and meta-analysis of prognostic factor studies. BMJ 2019;364:k4597.

22. Bramer WM. Reference checking for systematic reviews using Endnote. J Med Libr Assoc 2018;106(4):542-6.

23. Bramer WM, Milic J, Mast F. Reviewing retrieved references for inclusion in systematic reviews using EndNote. J Med Libr Assoc 2017;105(1):84-7.

24. Moons KG, de Groot JA, Bouwmeester W, Vergouwe Y, Mallett S, Altman DG et al. Critical appraisal and data extraction for systematic reviews of prediction modelling studies: the CHARMS checklist. PLoS Med 2014;11(10):e1001744.

25. Hayden JA, van der Windt DA, Cartwright JL, Cote P, Bombardier C. Assessing bias in studies of prognostic factors. Ann Intern Med 2013;158(4):280-6.

26. WHO Collaborating Centre for Drug Statistics Methodology. ATC/DDD Index 2023 2023 [cited 2023 30-03-2023]. Available from: URL: https://www.whocc.no/atc_ddd_index/.

27. Favril L, Yu R, Uyar A, Sharpe M, Fazel S. Risk factors for suicide in adults: systematic review and meta-analysis of psychological autopsy studies. Evid Based Ment Health 2022;25(4):148-55.

28. Borenstein M, Hedges LV, Higgins JPT, Rothstein HR. Introduction to Meta-Analysis. John Wiley & Sons, Ltd.; 2009.

29. Higgins JP, Thompson SG. Quantifying heterogeneity in a meta-analysis. Stat Med 2002;21(11):1539-58.

30. Higgins JP, Thompson SG, Spiegelhalter DJ. A re-evaluation of random-effects meta-analysis. J R Stat Soc Ser A Stat Soc 2009;172(1):137-59.

31. Harrer M, Cuijpers P, A FT, Ebert DD. Doing Meta-Analysis With {R}: A Hands-On Guide. 1st ed. Boca Raton, FL and London}: Chapman & Hall/CRC Press; 2021.

32. Sterne JA, Sutton AJ, Ioannidis JP, Terrin N, Jones DR, Lau J et al. Recommendations for examining and interpreting funnel plot asymmetry in meta-analyses of randomised controlled trials. BMJ 2011;343:d4002.

33. Balduzzi S, Rücker G, Schwarzer G. How to perform a meta-analysis with {R}: a practical tutorial. Evidence-Based Mental Health 2019;22:153-60.

34. Peel NM, Jones LV, Berg K, Gray LC. Validation of a Falls Risk Screening Tool Derived From InterRAI Acute Care Assessment. Journal of Patient Safety 2021;17(8):e1152-e6.

35. Mecocci P, Von Strauss E, Cherubini A, Ercolani S, Mariani E, Senin U et al. Cognitive impairment is the major risk factor for development of geriatric syndromes during hospitalization: Results from the GIFA study. Dementia and Geriatric Cognitive Disorders 2005;20(4):262-9.

36. Robinson K, Dennison A, Roalf D, Noorigian J, Cianci H, Bunting-Perry L et al. Falling risk factors in Parkinson's disease. NeuroRehabilitation 2005;20(3):169-82.

37. Kvelde T, McVeigh C, Toson B, Greenaway M, Lord SR, Delbaere K et al. Depressive symptomatology as a risk factor for falls in older people: systematic review and meta-analysis. J Am Geriatr Soc 2013;61(5):694-706.

38. de Vries M, Seppala LJ, Daams JG, van de Glind EMM, Masud T, van der Velde N et al. Fall-Risk-Increasing Drugs: A Systematic Review and Meta-Analysis: I. Cardiovascular Drugs. J Am Med Dir Assoc 2018;19(4):371 e1- e9.

39. By the American Geriatrics Society Beers Criteria Update Expert P. American Geriatrics Society 2019 Updated AGS Beers Criteria(R) for Potentially Inappropriate Medication Use in Older Adults. J Am Geriatr Soc 2019;67(4):674-94.

40. Caraci F, Enna SJ, Zohar J, Racagni G, Zalsman G, van den Brink W et al. A new nomenclature for classifying psychotropic drugs. Br J Clin Pharmacol 2017;83(8):1614-6.

41. Mathur MB, VanderWeele TJ. Methods to Address Confounding and Other Biases in Meta-Analyses: Review and Recommendations. Annu Rev Public Health 2022;43:19-35.

42. Ishibashi Y, Nishitani R, Kato T, Chiba S, Ashidate K, Ishiwata N et al. Association of drugs with special caution in the guidelines with falls: A case–control and case–crossover study in Japan. Geriatrics and Gerontology International 2021;21(3):285-90.

43. Grinspun D, Ireland S, Lam R. Preventing Falls and Reducing Injury from Falls. Toronto, ON, Canada: Registered Nurses' Association of Ontario; 2017.

44. National Instititute for Health and Care Excellence (NICE). Falls in older people: assessing risk and prevention. United Kingdom: National Instititute for Health and Care Excellence (NICE); 2013.

45. Sherrington C, Tiedemann A, Fairhall N, Close JC, Lord SR. Exercise to prevent falls in older adults: an updated meta-analysis and best practice recommendations. N S W Public Health Bull 2011;22(3-4):78-83.

Figure legends

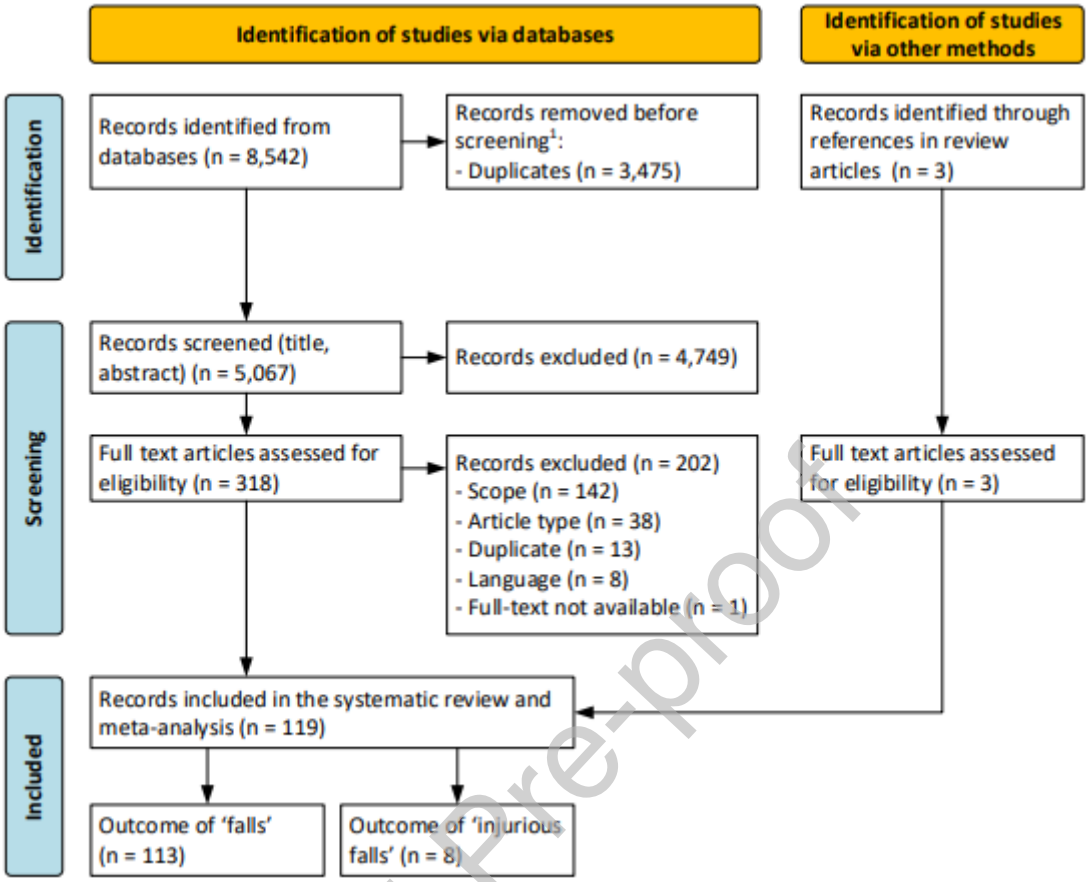

Fig 1. Flow-chart. Flow-chart showing the flow of articles through the identification, screening, and review process according to the PRISMA template. Two studies reported both falls and injurious falls as outcomes. ([1] using an automated deduplication tool)

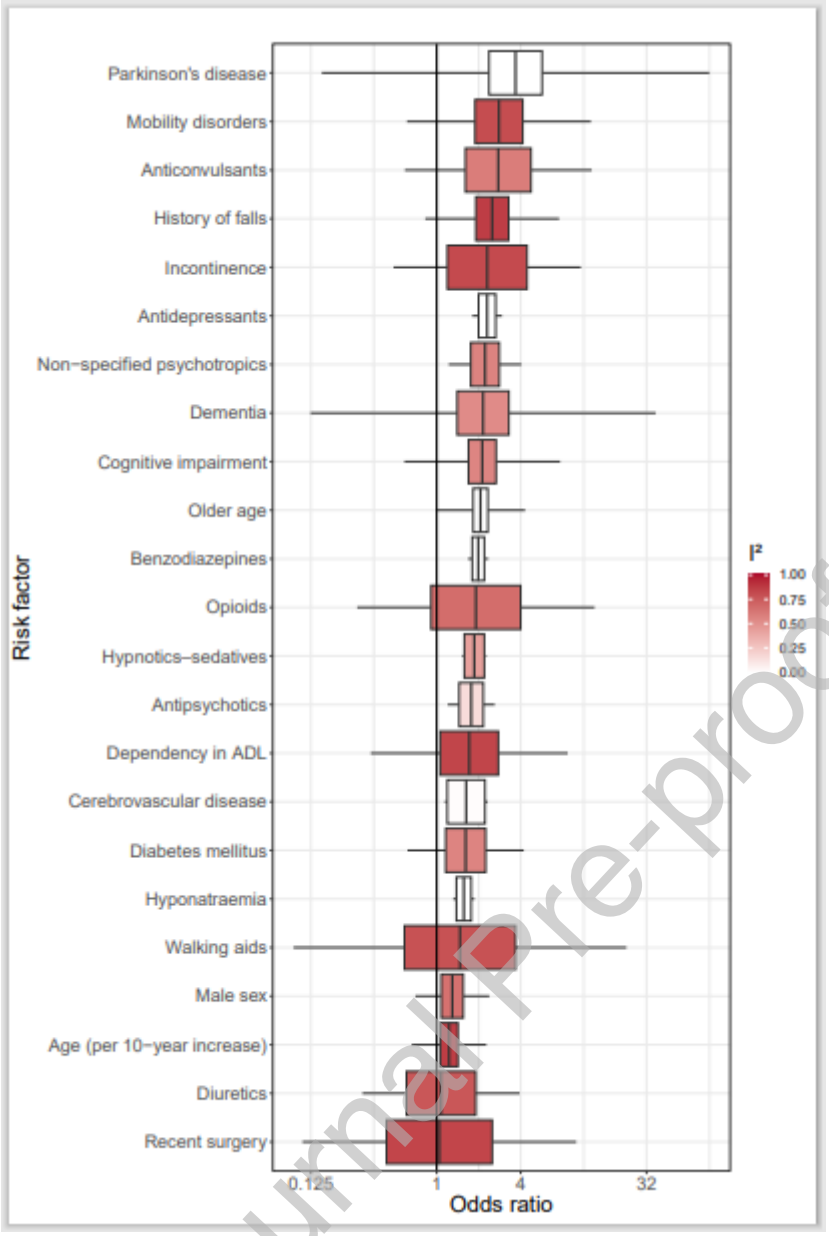

Fig 2. Risk factors for in-hospital falls (adjusted odds ratios). Pooled effect estimates of falls among the studies with a low-to-moderate risk of bias (primary analysis). Effect estimates adjusted for sex and age, at least, were included, indicating 95% confidence intervals (bars) and 95% prediction intervals (lines). The darker the red filling, the higher the heterogeneity (I^2). (ADL, basic activities of daily living).

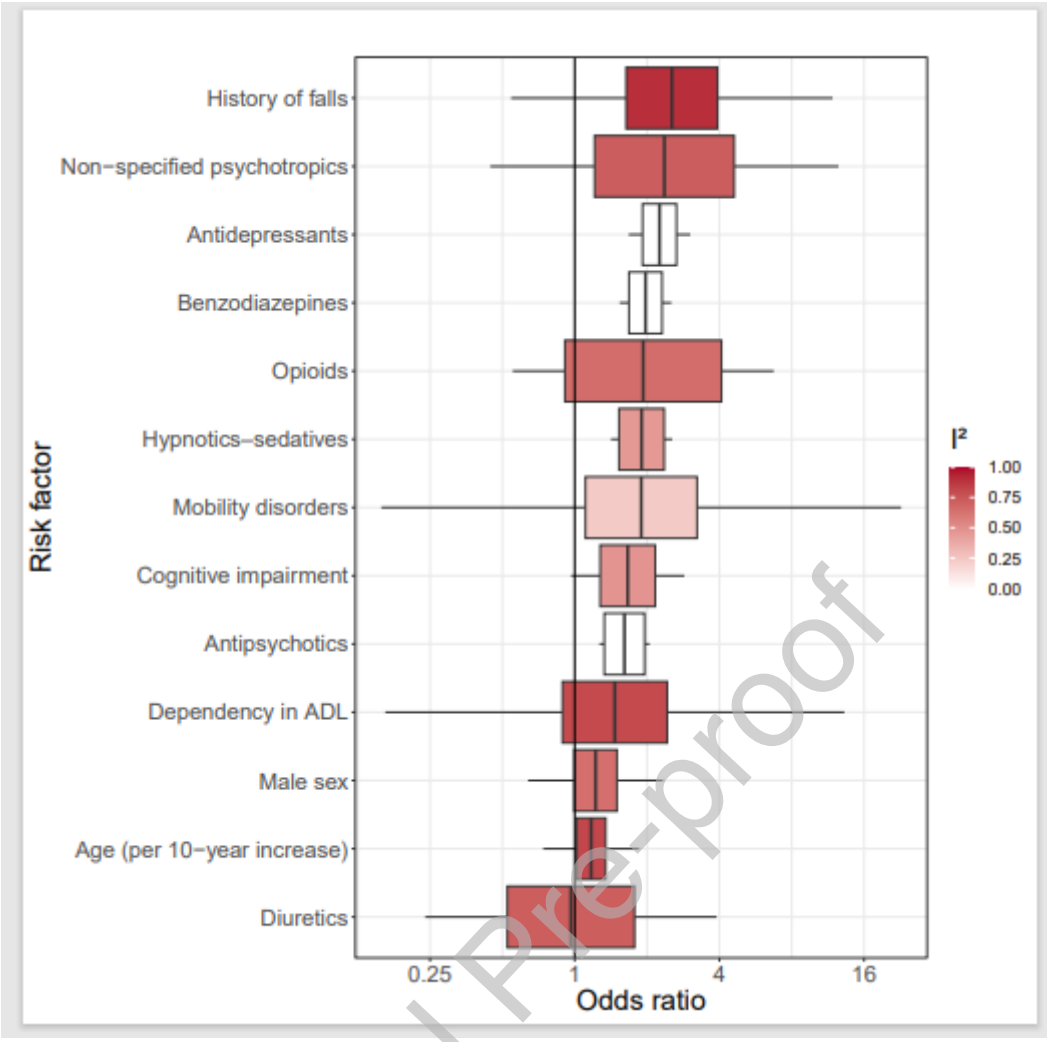

Fig 3. Risk factors for in-hospital falls. Pooled effect estimates of falls among the studies with a low-to-moderate risk of bias and including crude estimates (secondary analysis), indicating 95% confidence intervals (bars) and 95% prediction intervals (lines). The darker the red filling, the higher the heterogeneity (I^2). (ADL, basic activities of daily living; hyponatremia, 135 mmol/l of sodium in blood or below; older age, aged 65–70 years old or more).