

SYSTEMATIC REVIEW

The role of cognitive impairment in fall risk among older adults: a systematic review and meta-analysis

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Abstract

Background: cognitive impairment is an established fall risk factor; however, it is unclear whether a disease-specific diagnosis (i.e. dementia), measures of global cognition or impairments in specific cognitive domains (i.e. executive function) have the greatest association with fall risk. Our objective was to evaluate the epidemiological evidence linking cognitive impairment and fall risk.

Methods: studies were identified through systematic searches of the electronic databases of MEDLINE, EMBASE, PsychINFO (1988–2009). Bibliographies of retrieved articles were also searched. A fixed-effects meta-analysis was performed using an inverse-variance method.

Results: twenty-seven studies met the inclusion criteria. Impairment on global measures of cognition was associated with any fall, serious injuries (summary estimate of OR = 2.13 (1.56, 2.90)) and distal radius fractures in community-dwelling older adults. Executive function impairment, even subtle deficits in healthy community-dwelling older adults, was associated with an increased risk for any fall (summary estimate of OR = 1.44 (1.20, 1.73)) and falls with serious injury. A diagnosis of dementia, without specification of dementia subtype or disease severity, was associated with risk for any fall but not serious fall injury in institution-dwelling older adults.

Conclusion: the method used to define cognitive impairment and the type of fall outcome are both important when quantifying risk. There is strong evidence global measures of cognition are associated with serious fall-related injury, though there is no consensus on threshold values. Executive function was also associated with increased risk, which supports its inclusion in fall risk assessment especially when global measures are within normal limits.

Keywords: *accidental falls, cognition, risk factors, systematic review, meta-analysis, elderly*

Introduction

Falls in older adults are a major public health concern as approximately 30% fall at least once each year. Postural stability is a complex skill dependent upon the coordination of motor and sensory systems to perceive environmental stimuli and respond to perturbations to control body movement [1, 2]. The motor and sensory systems are linked by

higher order neurological processes and cognition, which are required for planning movements, divided attention and responding to changes within the environment [1]. Indeed, recent research has demonstrated cognition has a key role in the regulation of gait and balance in older adults [3].

Cognitive impairment has been identified as a fall risk factor in clinical practice guidelines; however, there are limited details how to quantify impairment and which

dimensions of cognition should be evaluated [4]. It is unclear whether a disease-specific diagnosis (i.e. dementia or mild cognitive impairment), a measure of global cognitive function or the evaluation of specific cognitive domains (i.e. executive function (EF) or memory), regardless of disease diagnosis, are associated with an increased fall risk. Current research has shown that subtle changes in cognition, specifically in EF, in the absence of dementia contribute to postural instability [5, 6]. Despite the emerging role of EF in the pathophysiology of postural instability, it is uncertain if EF testing should be recommended for fall risk evaluation.

Therefore, a critical analysis of the literature may provide further insight into which methods of cognitive assessment most strongly predict fall risk and if a specific domain, such as EF, plays a major role as suggested. Cognitive function has not yet received a structured critical evaluation as a fall risk factor.

The purpose of this review was to critically evaluate the evidence connecting cognitive impairment to falls in community and institution-dwelling older adults. Our specific objectives were: (i) to evaluate the association of cognitive impairment on fall risk (specifically the outcomes of any fall, recurrent falls and falls with injury), (ii) to explore differences in the association of cognitive impairment on fall risk between community and institution-dwelling older adults and (iii) to identify the association between disease diagnosis, global measures of cognition and specific domains of cognitive function with fall risk.

Methods

Search strategy and information sources

A literature search, without language restriction, identified articles published between 01/1988 and 12/2010. The following electronic databases were searched: MEDLINE, Pubmed, EMBASE and PsychINFO. The following MeSH subject terms and keywords were used: 'accidental falls', 'falling', prospective studies, risk factors, risk assessment, risk reduction, aged, aged 80 and over, elderly, ageing, fractures, bone, hip fracture, radius fracture, ulna fracture, wrist fracture and humerus fracture. A hand search of the bibliographic references of extracted articles and existing reviews was conducted to identify studies not captured in the electronic searches.

Study eligibility criteria

Abstracts were screened and potentially relevant articles obtained. Retrieved articles were independently evaluated by two people to determine whether they met the following inclusion criteria for full review; any disagreement was resolved by consensus:

- Sample participants ≥ 60 years.
- Prospective cohort design, at least 1 year duration, with minimum 80% sample follow-up. Fall prevention trials

were excluded, as the intervention may have successfully modified deficits.

- Samples comprised community or institution-dwelling populations. Studies of acute care settings with short-term length of stay were not included.
- 'Falls' was the primary outcome, including 'any fall', 'recurrent falls' and 'injurious falls'. For the evaluation of extremity fractures, an explicit statement was needed that fractures were the result of falling.
- Cognitive function was measured at baseline. Measurement of cognitive function had to be explicitly detailed in the methods or referenced for validity and/or reliability.
- Inclusion and exclusion criteria and demographic information were reported.
- Confounding factors were reported and used in multivariable regression analysis to generate adjusted risk estimates.
- Samples did not comprise a disease-defined population (i.e. stroke, Parkinson's disease and dementia).

For a study to be considered within the disease-specific diagnosis category, the study needed to have analysed the association between fall risk and dementia, a dementia sub-type or mild cognitive impairment; a measure of global cognitive status was defined as the utilisation of general cognitive screening tests that evaluate several cognitive domains in a single summary score and specific cognitive domains were classified according to specific test demands and the mental processes required to execute them (i.e. EF, memory).

Methodological quality assessment

Each article meeting the inclusion criteria was independently assessed by two raters for reporting quality using two scales. The first scale, by Tooth *et al.* [7], is a validated and reliable list of criteria for evaluating threats to internal and external validity in observational studies. This scale has 33 questions covering the areas of recruitment, data collection, biases, data analysis, study population and generalisability. The maximum possible score is 33, a higher score indicating greater reporting quality. The second scale by Stalenhoef *et al.* [8] has 10 criteria and was developed for evaluating falls research in older adults. The higher the score the more complete the reporting of details.

Data extraction and analysis

Articles selected for full review had the following information extracted: authors, country, date of publication, sample size at baseline and follow-up, demographic information (percentage female, mean age), inclusion/exclusion criteria, fall definition, method of fall ascertainment, type of fall outcome, cognitive function measurement scale, length of follow-up and percentage of sample who sustained the fall outcome.

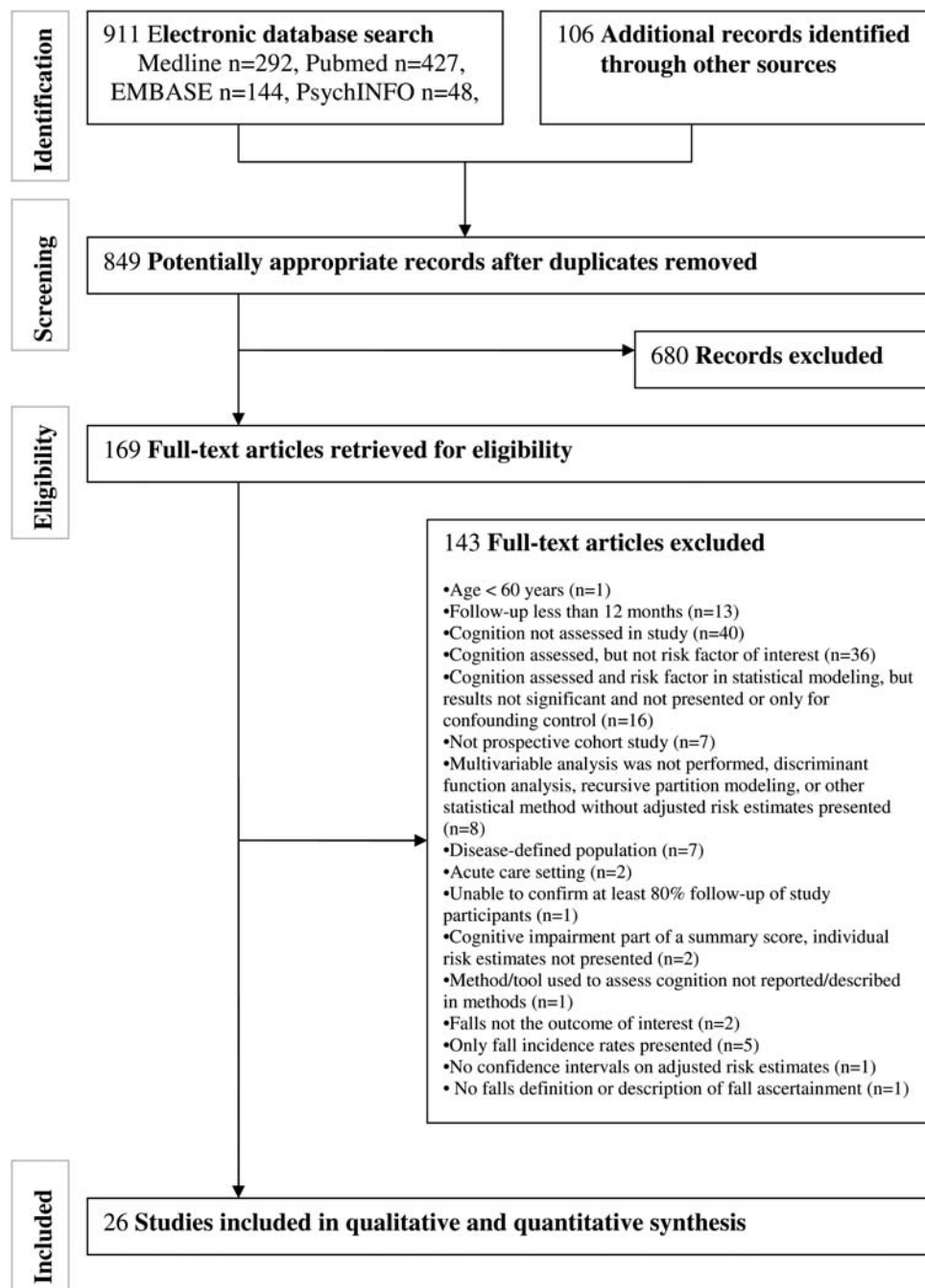


Figure 1. Flow diagram of literature search.

Data analysis information extracted was the adjusted risk estimates and 95% confidence intervals (CI). Variables were re-coded when required to ensure risk was quantified in the same direction for all studies (i.e. the presence of cognitive deficits increased fall risk, with the lowest risk category as the reference level). A fixed effects meta-analysis was performed on the adjusted estimates to generate summary values. Statistical tests of homogeneity were performed using Cochran's Chi-squared test for homogeneity (Q) and the percentage of total variation across studies attributable to heterogeneity (I^2) [9]. Statistical analysis was performed using the software

program Computer Programs for Epidemiologists (WINPEPI) version 11.8 [10].

Results

Study selection and characteristics

A total of 849 abstracts were identified, 169 full-text articles were kept for detailed analysis. (Figure 1; see Supplementary data are available in *Age and Ageing* online, Appendix 1 for excluded articles) Twenty-six articles met the inclusion criteria (Table 1) [11–36]. Eleven studies are

Table I. Details of studies meeting selection criteria included in this systematic review

Author	Characteristics of study sample (sample size, % female, mean (SD) age, population-type)	Length of follow-up (years)	Outcome (<i>n</i> , % of sample to sustain fall outcome)	Number of people with cognitive impairment stratified by fall outcome status	Quality of reporting evaluation ^a
Tinetti <i>et al.</i> [30], USA	336, 55%, 78.3 (5.1), CD	1	Any fall (<i>n</i> = 108, 32%)	F = 16/108, NF = 8/228	25/10
Campbell <i>et al.</i> [15], New Zealand	761, 61%, mean age not reported, CD and ID	1	Any fall (<i>n</i> = 266, 35%)	Women: F = 9/152, NF = 7/313; Men: F = 2/68, NF = 2/228	20/10
Nevitt <i>et al.</i> [25], USA	325, 82%, 70.3, CD	1	Injurious fall (major injury—fracture, joint dislocation, laceration requiring sutures) <i>n</i> = 25, 6%	Data not available in manuscript	18/10
Clark <i>et al.</i> [18], Australia	81, 86%, mean age not reported, ID	1	Any fall, <i>n</i> = 42, 52%	Data not available in manuscript	17/10
Tinetti <i>et al.</i> [31], USA	1,103, 73%, 79.6 (5.3), CI	1	Injurious falls—serious fall injury (<i>n</i> = 123, 12%)	Data not available in manuscript	25/10
Tinetti <i>et al.</i> [32], USA	568, 74%, mean age not reported, CD	3	Injurious falls—serious fall injury (<i>n</i> = 123, 12%)	Data not available in manuscript	25/10
Luukinen <i>et al.</i> [23], Finland	145, 76%, 81.2 (5.8), ID	2	Recurrent falls (at least two falls within 6 months) (<i>n</i> = 52, 56%)	F = 36/51, NF = 21/35	22/10
Luukinen <i>et al.</i> [24], Finland	1,016, 50%, 76.1 (4.9), CD	2	Recurrent falls (at least two falls within 12 months) (<i>n</i> = 112, 11%)	Data not available in manuscript	20/10
Thapa <i>et al.</i> [29], USA	1,228, 77%, mean age not reported, ID	1	Injurious falls—serious injuries (head injury with altered consciousness, fracture, joint dislocations or sprains, or sutured lacerations)—nr	Data not available in manuscript	21/10
Northridge <i>et al.</i> [26], USA	325, 82%, mean age not reported, CD	1	Single fall (<i>n</i> = 109, 33%); recurrent falls (2 falls: <i>n</i> = 82, 17%; 3+ falls: <i>n</i> = 26, 8%)	Data not available in manuscript	17/10
Kiely <i>et al.</i> [21], USA	18,855, 74%, mean age not reported, ID	1	Any fall (<i>n</i> = 5,519, 29%)	Data not available in manuscript	19/9
Tromp <i>et al.</i> [33], the Netherlands	1,469, 51%, 72.6 (6.6), CD	3.2	Any fall (<i>n</i> = 464, 31%); recurrent falls (<i>n</i> = 217, 14.8%); fractures (<i>n</i> = 85, 6%)	Data not available in manuscript	20/10
Bueno-Cavanillas <i>et al.</i> [14], Spain	190, nr, mean age not reported, ID	1	Any fall (<i>n</i> = 65, 64%)	Data not available in manuscript	22/10
Vogt <i>et al.</i> [36], USA	9,704, 100%, mean age not reported, CD	9.8	Injurious fall—distal radius fracture (<i>n</i> = 527, 5%)	Data not available in manuscript	19/9
van Schoor <i>et al.</i> [35], the Netherlands	1,437, 51%, 75.6 (6.6), CD and ID	3	Recurrent falls (≥2 falls within 6 months) (<i>n</i> = 370, 26%)	Data not available in manuscript	19/10
Kron <i>et al.</i> [22], Germany	472, 77%, 84.0 (7.0), ID	1	Any fall (<i>n</i> = 247, 52%)	Data not available in manuscript	19/10
van Doorn <i>et al.</i> [34], USA	2,015, 70.4%, 81.4 (7.6), ID	2	Any fall (<i>n</i> = 1,017, 51%)	Data not available in manuscript	21/10
Bergland and Wyller [13], Norway	307, 100%, 80.8, CD	1	Injurious falls—serious injuries (head injury with altered consciousness, fracture, joint dislocations or sprains, or sutured lacerations) (<i>n</i> = 74, 24%)	Data not available in manuscript	24/10
Chu <i>et al.</i> [17], Hong Kong	1,517, 49.2%, 73.2 (6.3), CD	1	Any fall (<i>n</i> = 294, 19%); recurrent falls	Data not available in manuscript	22/10
Anstey <i>et al.</i> [11], Australia	539, 52.9%, mean age not reported, CD	8	Any fall (<i>n</i> = 132, 24%)	F = 118/492, NF = 14/43	20/9
Pluijm <i>et al.</i> [27], the Netherlands	1,365, 51.1%, 75.3 (6.4), CD	3	Recurrent falls (≥2 falls within a 6-month period during 3-year follow-up) (<i>n</i> = 755, 55.3%)	Data not available in manuscript	20/10
Sambrook <i>et al.</i> [28], Australia	2,005, 79.3%, 86.2, ID	Median follow-up 1.93 years	Injurious fall (any fracture) (<i>n</i> = 315, 15.7%)	MMSE score: (i) 0–17 F = 69/585, NF = 158/974; (ii) 18–23 F = 88/446, NF = 158/974	19/10
Beauchet <i>et al.</i> [12], France	213, 83.6%, 85.3, CD	1	Any fall (<i>n</i> = 153, 72%)	F = 14/20, NF = 93/193	18/10

Chen <i>et al.</i> [16], Australia	1,342, 77.1%, 86.0 (7.0), ID	2	Injurious falls (any fracture) (<i>n</i> = 207, 20%)	MMSE score (i) 0–17; F = 58/408, NF = 133/609; (ii) 18–23; F = 78/317, NF = 133/609	19/10
Gleason <i>et al.</i> [19], USA	172, 78%, 80.4 (7.7), CD	1	Any fall (nr)	Data not available in manuscript	17/10
Herman <i>et al.</i> [20], Israel	262, 60.3%, 76.3 (4.3), CD	2	Any fall (<i>n</i> = 131, 50%)	Data not available in manuscript	17/10

nr, not reported; CD, community-dwelling older adults; ID, institution-dwelling older adults; F, sustained a fall over the duration of the study; NF, did not sustain a fall over the duration of the study.
^aQuality of reporting score reported as first number: Tooth *et al.* [7]; second number: Stalenhoef *et al.* [8].

derived from four common data sources: a cohort study from San Francisco, USA [25, 26]; a cohort study from New Haven, USA [31, 32]; the Longitudinal Study on Aging Amsterdam (LASA) [27, 33, 35] and the Fracture Risk Epidemiology in the Elderly (FREE) Study [16, 28] from Australia. Each publication from the same data source had a different fall outcome. Eight studies of community-dwelling older adults excluded participants based on cognitive status using unable to follow simple instructions [25, 26, 30–32] and MMSE scores indicating severe cognitive impairment [12, 13, 20].

The average quality of reporting score using the Tooth *et al.* [7] scale was 19.4 (range 17–25) and the Stalenhoef *et al.* [8] scale was 9.5 (range 9–10). Deficiencies on the Tooth *et al.* [7] scale occurred in the areas of reporting and handling missing data, and a lack of either a qualitative or quantitative analysis of bias. The deficiencies identified with the Stalenhoef *et al.* [8] scale were a lack of reporting a definition of a fall. A ceiling effect of scores was present using the Stalenhoef *et al.* [8] scale, with scores at either 9 or 10.

The fall outcomes presented were any fall, recurrent falls and injurious falls. The fall definition varied slightly across studies, creating heterogeneity even within the same fall outcome. Seven studies excluded falls due to a single major intrinsic event or a violent blow [13, 16, 18, 19, 28, 30, 36], which would have evaluated factors related to impairment of sensorimotor function. A broader definition of falls used in the other studies allowed for the inclusion of major intrinsic events, which would have captured additional falls resulting from cardiovascular and neurological causes such as syncope, transient ischaemic attacks and stroke.

In the category of injurious falls, there were no studies to evaluate a general outcome of ‘any injury’. Specific sub-categories of fall-related injuries were major or serious injuries [13, 25, 29, 31, 32], any fracture [16, 28] and distal radius fractures [36].

Among community-dwelling older adults, fall risk ranged from 19 to 50% [17, 20] for any fall, 11–55.3% [24, 27] for recurrent falls, 6–24% [13, 25] for any serious injury, and the risk of a distal radius fractures was 5% [36]. In the institution-dwelling populations, risk for any fall was 29–64% [14, 21] and for recurrent falls was 56% [23]. Length of follow-up also varied, with 1 year being the most common time-frame for the outcomes of any fall and recurrent falls [12–15, 18, 19, 21, 22, 25, 26, 29–31]. Most articles did not provide the number of people with cognitive impairment who did or did not sustain the given study’s fall outcome of interest.

Falls calendars were the most common method for fall ascertainment. These studies reported policies to contact participants if calendars were not received and when falls were reported, which would enhance accurate outcome ascertainment and sample follow-up. Studies evaluating fracture outcomes combined radiological confirmation of fractures with surveillance of hospital records. Studies in an institutional setting used incident reports and nursing charts to record fall events.

Table 2. Summary of main findings from review of the studies for the association of cognitive impairment on falls in older adults

Measurement of cognitive impairment	Fall outcome				
	Any fall	Recurrent falls	Fall with serious injury	Fall with fracture	Fall with distal radius fracture
.....					
Community-dwelling older adults					
Disease-specific diagnosis					
Dementia	+	+			
Measures of global cognition	+++**	*****	+++++	*	+
Specific cognitive domains					
Executive function	++*	*	+		
Immediate recall	-				
Verbal reasoning	-				
Processing speed	*		+		
Institution-dwelling older adults					
Disease-specific diagnosis					
Dementia	+-		-		
Severity of dementia			*		
Measures of global cognition	++*	***	*	*	
Specific cognitive domains					
Combined community and institution-dwelling older adults					
Disease-specific diagnosis					
Measures of global cognition	-*				
Specific cognitive domains					
Non-verbal/ abstract reasoning		-			
Immediate recall		*			
Processing speed		-			

Each indicator (+, *, -) represents one study population. The plus sign (+) indicates there is evidence that cognitive impairment as defined is associated with an increased fall risk. The minus sign (-) indicates there was no evidence of association. The asterisk (*) indicates results were not presented for adjusted analysis though variable was evaluated. See Supplementary data are available in *Age and Ageing* online for listing of information per study.

Assessment of cognitive function

Overall, cognitive impairment was not consistently associated with an increased fall risk in community or institution-dwelling populations, though the majority of the studies (56%) showed a significant association (Table 2; see Supplementary data are available in *Age and Ageing* online, Table 3).

Cognitive impairment as a disease-specific diagnosis and fall risk

A disease-specific diagnosis of dementia, without specification of dementia sub-type or severity, was used in three studies [17, 18, 34]. The clinical judgment that a person had dementia was associated with any fall and recurrent falls among community-dwelling older adults [17], and any fall in institution-dwelling older adults [18]. The diagnosis of dementia using the DSM-III criteria was associated with any fall in institution-dwelling older adults [34]. Dementia severity in institution-dwelling individuals was not associated with serious fall-related injury [34].

Cognitive impairment on measures of global cognition and fall risk

Sixteen studies used a measure of global cognitive status to determine impairment, but only six of these studies (38%)

demonstrated a statistically significant association to any of the fall outcomes. The MMSE was the most common scale used and when dichotomised was associated with serious fall-related injury (<27) and distal radius fracture (≤ 23) in community-dwelling older adults [13, 25, 31, 32]. Gleason *et al.* [19] found the risk of any fall increased by 20% for each point decrease on the MMSE among community-dwelling older adults. The short portable mental status questionnaire, when dichotomised at ≥ 5 errors, was associated with any fall in community-dwelling older adults.

Cognitive impairment on specific cognitive domains and fall risk

EF, using the Trail Making Test B and a computerised neuropsychological test battery, was associated with any fall and serious fall-related injuries in community-dwelling older adults [20, 25, 26]. Herman *et al.* [20] found that EF impairment in healthy older adults, assessed using a computerised neuropsychological test battery, was associated with a three times increased odds of sustaining any fall. Processing speed was also associated with serious fall-related injuries in community-dwelling older adults [11]. Van Schoor *et al.* [35] found that measures of non-verbal and abstract reasoning, and processing speed were not associated with an increased fall risk among institution-dwelling older adults.

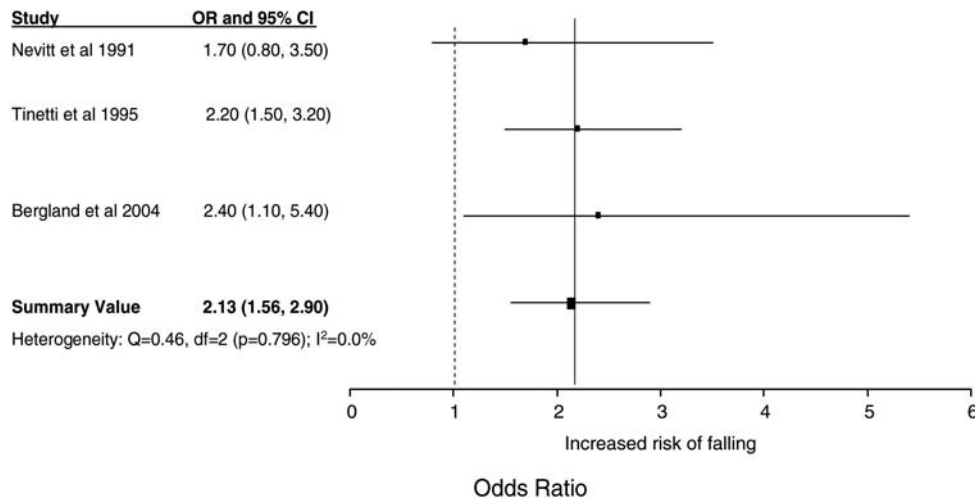


Figure 2. Forest plot for risk of serious fall-related injuries among community-dwelling older adults using the Mini-Mental State Examination (dichotomised at a score <26).

Meta-analysis

To facilitate comparison with previous published literature, a meta-analysis was initially performed for cognitive impairment, regardless of assessment method, on falls stratified by dwelling and fall outcome. Risk estimates reported in OR and RR could not be combined as the fall outcomes were common (>10%); so the OR will over-estimate the RR and they are therefore not interchangeable. Among community-dwelling older adults, summary risks were for any fall the OR = 1.32 (1.18–1.49) ($Q = 15.54$, P -value = 0.004; $I^2 = 74.3\%$), a serious fall-related injury was OR = 2.33 (1.61–3.36) ($Q = 1.06$, P -value = 0.303; $I^2 = 5.9\%$) and a fall resulting in a fracture was RR = 1.78 (1.34–2.37) ($Q = 0.63$, P -value = 0.428; $I^2 = 0.0\%$). In the institution-dwelling population, the available data only allowed calculation of a summary estimate for any fall, an OR = 1.88 (1.54–2.30) ($Q = 3.76$, $P < 0.001$; $I^2 = 46.9\%$). These values need to be interpreted with caution.

As the qualitative and quantitative analysis indicated substantial heterogeneity in the above analyses, a sensitivity analysis was performed by method of cognitive assessment in line with our objectives (Figure 2). The lack of reporting non-significant results in the articles constrained the sensitivity analysis. The summary risk estimates in community-dwelling older adults for global measures of cognition (MMSE <26) on serious fall-related injuries was OR = 2.13 (1.56, 2.90) ($Q = 0.46$, P -value = 0.796; $I^2 = 0.0\%$) and for EF impairment was OR = 1.44 (1.20, 1.73) ($Q = 3.96$, P -value = 0.047; $I^2 = 74.4\%$).

Discussion

This systematic review and meta-analysis confirms that cognitive deficits detected on clinical assessment are associated with an increased fall risk in community and institution-dwelling older adults. Importantly, our findings

strongly suggest that how cognitive impairment is defined and assessed is essential in identifying individuals at risk of falls and is paramount to facilitate knowledge translation into clinical practice.

Measures of global cognitive status were not consistently associated with falls, but the MMSE was strongly associated with serious fall-related injury in community-dwelling older adults. On the other hand, measures of specific cognitive domains, such as EF impairment, were consistently associated with an increased fall risk. Notably, impairment in EF can be present in people who are healthy and well-functioning without impairment on measures of global cognitive status [20]. A diagnosis of dementia, in both community and institution-dwelling older adults, confers a high risk for any fall and recurrent falls.

The methodological quality of the reviewed articles was uniformly moderate to high, though there are some important findings to emphasise. The routine exclusion of the severest cognitively impaired from studies among community-dwelling people creates a selection bias and restricted range of the cognitive scores, ultimately limiting the true range of the variable in the population [37]. Measures of global cognition tended to be dichotomised in the analysis, though clinically useful, it can lead to a severe loss of efficiency, or reduced power, to find an association to falls. In contrast, the majority of studies that evaluated measures of global function and specific cognitive domains as continuous variables found significant associations to falls. Lastly, falls among community-dwelling older adults with cognitive impairment may have been under-reported compared with their cognitively intact peers. In contrast, falls in an institutional setting may be more accurately enumerated regardless of the cognitive status of the resident. These methodological issues may explain the lack of statistically significant associations among the studies between cognitive impairment and falls as their effect is to bias risk estimates towards the null.

The epidemiological literature has not been previously reviewed in sufficient detail to identify the specific cognitive measurement scales that are associated with fall risk. The present study helps bridge the gap between the risk factor literature and methods of quantifying cognitive impairment to provide validation for their clinical practice use to identify increased fall risk. While a comprehensive neuropsychological assessment is not possible for all people, particularly in the screening situation for fall risk, the evaluation of cognition can be easily performed in the clinical setting to obtain valuable information.

The meta-analysis results, not stratified by method of cognitive assessment, are more conservative than previous published results due to a more rigorous methodology, but still lack precision and should be interpreted with caution. The validity of previous summary estimates can be questioned as adjusted and unadjusted values, studies with different fall outcomes, different study samples (community versus institution-dwelling, disease-defined populations) and different measures of risk (odds ratios versus relative risk) have been combined [38–40]. Additionally, as there was a tendency for non-significant results to go unreported, any summary value would over-estimate risk. (see Supplementary data are available in *Age and Ageing* online, Table 3)

Fall risk was greater among older adults living in an institutional setting than the community. This difference in the risk magnitude by dwelling is consistent with older adults in an institutionalised setting represent frailer, more functionally compromised older adults with a potentially greater cognitive or dementia disease burden. This review does not provide an explanation for the increased fall risk in community or institution-dwelling older adults. Cognitive impairment can be a proxy for many possible factors associated with falls such as behavioural issues, lack of insight with resultant engagement in risk-taking activity, mobility deficits and difficulty with performance of activities requiring divided attention. Research within homogeneous samples of cognitively impaired older adults can further help identify the underlying contributing factors and mechanisms which can enhance fall prevention interventions [41].

Limitations

There are some limitations to this systematic review. A funnel plot was not performed to evaluate publication bias as they are less useful in observational studies as bias and confounding represent a greater threat for introducing heterogeneity [42]. In extracting data from the included articles, there was a tendency of authors to report only statistically significant results, as not all variables that entered the regression modelling had estimates reported. Very few of the included studies had the primary objective to evaluate cognitive impairment as an *a priori* fall risk factor of interest; the majority of articles were risk factor

generation studies, which do not include confounding control in the adjusted analysis.

Conclusions

Cognitive impairment is associated with an increased fall risk, but the method used to define cognitive impairment and the types of fall outcome are both important in quantifying risk. Measures of global cognitive status are not sufficient to identify increased fall risk and there is no consensus from the literature on thresholds to facilitate implementation in clinical practice. Recent research has identified EF impairment with an elevated fall risk. Most importantly, subtle impairment in EF can exist in people who are healthy and well functioning conferring a threefold increased fall risk. Assessment of EF should be included as part of a falls risk assessment in older adults especially if global measures are within normal limits. Further epidemiological research is suggested where cognitive impairment is the primary exposure of interest on fall risk in order to enhance the precision and estimation of the risk magnitude and knowledge translation of into clinical practice.

Key points

- The method used to define cognitive impairment and the types of fall outcome are both important to quantify risk.
- Global cognitive impairment (MMSE <26) confers a moderate to high risk of serious fall-related injury, summary estimate of OR = 2.13 (1.56, 2.90).
- EF impairment was consistently associated with an increased fall risk, OR = 1.44 (1.20, 1.73).
- Since impairment in EF can be present despite normality in global cognitive status, assessment of this cognitive domain should be included as part of a falls risk evaluation in older adults.

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Authors' contributions

S.W.M., K.G. and M.M.O. developed the protocol; S.W.M. and K.G. performed the literature searching and data extraction; S.W.M. conducted data analysis; S.W.M., K.G. and M.M.O. participated in interpretation of data and manuscript preparation. MMO obtained funding support. All of the authors reviewed the manuscript prior to submission.

Conflicts of interest

None declared.

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Sponsor's role

None.

Supplementary data

Supplementary data mentioned in the text is available to subscribers in *Age and Ageing* online.

References

The long list of references supporting this review has meant only the most relevant are listed here and are represented by bold type throughout the text. The full list of references is available at *Age and Ageing* online. Supplementary data are available in *Age and Ageing* online Appendix 1.

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