A systematic review of risk prediction models for falls after stroke

This is a pre-copyedited, author-produced version of an article accepted for publication in the Journal of Epidemiology and Community Health following peer review. The version of record " Walsh ME, Horgan NF, Walsh CD, Galvin R. A systematic review of risk prediction models for falls after stroke. Journal of Epidemiology and Community Health. 2016;70(5):513-9" is available online at: http://dx.doi.org/10.1136/jech-2015-206475).

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Keywords: Systematic reviews; Falls; Stroke; Decision Making PR

Word count: 2749

Number of Tables: 2

Number of Figures: 1

What is already known on this subject?

Current prognostic research for falls after stroke consists of individual and disparate studies that propose modifiable risk factors, prognostic factors, physical measure cut-off scores, or multivariable risk prediction models. There is little clarity or consensus on how results could inform clinical decision-making.

What this study adds?

This review identifies risk prediction models for falls after stroke that require validation and impact measurement. It will facilitate future researchers in the appropriate measurement of prognostic factors for model validation, a key step in the development process of models that can be incorporated into clinical decision-making post stroke.

ABSTRACT

Background: Falls are a significant cause of morbidity after stroke. The aim of this review was to identify, critically appraise, and summarise risk prediction models for the occurrence of falling after stroke.

Methods: A systematic literature search was conducted in December 2014 and repeated in June 2015. Studies that used multivariable analysis to build risk prediction models for falls early after stroke were included. Two reviewers independently assessed methodological quality. Data relating to model calibration, discrimination (C-statistic) and clinical utility (sensitivity and specificity) were extracted. A narrative review of models was conducted. PROSPERO reference: CRD42014015612

Results: The 12 included articles presented 18 risk prediction models. Seven studies predicted falls among inpatients only and five recorded falls in the community. Methodological quality was variable. A C-statistic was reported for seven models and values ranged from 0.62 to 0.87. Models for use in the inpatient setting most frequently included measures of hemi-inattention, while those predicting community events included falls (or near-falls) history and balance measures most commonly. Only two studies reported any form of validation and none presented a validated model with acceptable performance.

Conclusion: A number of falls-risk prediction models have been developed for use in the acute and sub-acute stages of stroke. Future research should focus on validating and improving existing models, with reference to the Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis

(TRIPOD) guidelines to ensure quality reporting and expedite clinical implementation.

INTRODUCTION

Falls are a frequent in-hospital complication post-stroke, accounting for up to 40% of adverse events.[1] Patients who fall in hospital have longer lengths of stay, are more likely to experience functional decline and have an increased risk of falling on returning home.[1-3] Stroke survivors fall at almost twice the rate of healthy peers post-discharge, with the first-year prevalence of falls estimated at 50%.[3,4] Serious injuries from falls occur in around 5% of stroke survivors over this period.[5] Fallers demonstrate higher levels of anxiety, depression and fear.[6] Furthermore, the economic burden of falls after stroke is significant.[1]

Falls-risk assessment tools are considered fundamental for falls-prevention among older adults.[7] Falls-prediction models validated for older adults have shown poor predictive power among individuals after stroke however, possibly because they do not account for specific stroke effects.[8,9] Several studies have proposed prognostic factors for falling after stroke but many report univariable associations only.[10,11] Using cut-off scores on physical measures has also been examined [4]. Neither of these methods consider the multi-factorial nature of falls. A number of risk prediction models for falling after stroke have been developed using multivariable methods.[12,13] Before a multivariable risk prediction model can facilitate clinical decision-making it should be validated in an independent sample (broad validation) and its impact should be evaluated (impact analysis).[14,15]

The aim of this systematic review is to describe prediction models that have been derived, with or without validation, to estimate the risk of occurrence of falls within the first year after stroke. Secondary aims are to describe the differences in model content and performance across settings (hospital versus community) and outcomes, and to evaluate the methodological quality of these models.

METHODS

Study design

The protocol for this systematic review was registered with PROSPERO in December 2014 (Reference CRD42014015612).

Search strategy

A systematic literature search was conducted in December 2014 and repeated in June 2015. It included the following search engines from inception: MEDLINE, EMBASE, CINAHL, PsycINFO, Scopus, Web of Science, and the Cochrane Library. Keywords and MeSH terms were used to combine the topics of risk prediction, stroke and falls. Reference lists and citing articles were hand-searched. Please see the Online Supplemental Methods for the full search strings.

Study selection

Prospective and retrospective cohort studies and randomised control trials were included that recruited adults with stroke and measured a falls outcome. Studies were included that used multivariable methods to build a risk prediction model, and focused on the predictive ability of the whole model. Validation studies were included where the model had been derived in a stroke population. Studies that aimed to identify independent factors, or studies that focused on cut-off scores for physical measures, adjusting for demographic variables were excluded. Studies were excluded if over 50% of their participants were more than three months post-stroke at the time of index assessment, as the majority of motor and functional gains are made within this phase of stroke recovery.[16] No limits were placed on language.

Data extraction

Results were screened and irrelevant articles were excluded based on title and abstract. Full texts of potentially eligible articles were screened independently by two authors (MW, RG). Authors were contacted where necessary to determine eligibility. A data-extraction form was developed and piloted with reference to the CHARMS checklist.[17] Two review authors (MW, RG) independently extracted data from eligible articles.

Methodological quality assessment

Two review authors (MW, RG) independently assessed the risk of bias using a checklist developed by McGinn and colleagues.[18] Please see the Online Supplemental Methods for guidance notes developed by the authors apriori for each criterion. Differences in opinion were resolved by consensus.

Statistical analysis

Meta-analysis was not carried out due to variability in the factors included in risk prediction models and heterogeneity of studies. A narrative summary was conducted. Data relating to model calibration, discrimination (c statistic) and clinical utility (sensitivity and specificity) were extracted and presented where reported. The R^2 value was extracted as a measure of overall model performance.[19]

RESULTS

Study identification

The initial search yielded 4604 unique articles, of which 4424 were excluded based on title and abstract. Full texts of 180 articles were reviewed by two authors (RG, MW). Twelve articles were included in the final review.[3,12,13,20-28]

Figure 1. shows the flow of studies and details of exclusion. Sixteen studies that focussed on independent risk factors/ predictors for falls early after stroke were excluded from this review. Please see the Supplemental Table I (online only) for results of their multivariable analyses.

Study characteristics

Please see the Supplemental Table II (online only) for detailed characteristics of the included studies. The 12 included articles presented 18 risk prediction models. The geographic distribution of the studies was: Europe,[12,13,22,23] USA,[24,25,27,28] Australasia,[3,20] and Asia.[21,26] Sample sizes ranged from 32 [24] to 1104 [20] participants, with a total of 4315 participants across all studies. Eight of the models were developed to predict the occurrence of any fall,[13,20,21,24-26] while the remaining models focused on multiple or injurious falls, time taken to fall or number of falls.[3,12,20,22-24,27,28] Seven studies derived nine models in total to predict falls occurring in the inpatient setting after stroke, with the patients in most studies being followed-up for the duration of their hospital stay.[21-26,28] The other five studies derived nine models that predicted falls in the community setting or in a combination of settings. These studies reported longer follow-up periods of between six and 12 months.[3,12,13,20,27]

Methodological quality assessment

Table 1 presents the results of a quality assessment.[18] Two studies reported seven of the eight quality criteria.[13,23] Five papers did not present clear methods for combining the final components of the model to estimate risk for individuals.[20,25-28] In addition one study included some measures from the six-month assessment in the model thus preventing its use at the point of discharge.[20] Five studies presented seven models based on small sample sizes (there were less than 10 fall events per final predictor), [3,12,22,24,28] increasing the potential for unreliable parameter estimates.[29] Reporting was poor in the area of blinding of the outcome assessors, which was discussed in only one study.[24] Seven studies did not report loss to follow-up.[21-27] Only community studies reported loss to follow-up ranging from 6% to 19%.[3,12,13,20]

Table 1. Methodological quality assessment of studies

First author, year	Internal Validity				External Validity			
	Blind to predictors	Blind to outcome	Sample size	Clinically sensible	Important predictors	Predictor incidence >5%	Predictors defined	Outcome defined
Ashburn, 2008 [12]	N/R	Yes	No	Yes	Yes	Yes	Yes	Yes
Baetens, 2011 [13]	N/R	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Chen, 2015 [28]	N/R	Yes	No	N/R	Yes	Yes	Yes	No
Kerse, 2008 [20]	N/R	Yes	Yes	N/R	Yes	Yes	No	No
Mackintosh, 2006 [3]	N/R	Yes	No	Yes	Yes	Yes	Yes	Yes
Nakagawa, 2008 [21]	N/R	Yes	Yes	Yes	Yes	No	N/R	Yes
Nyberg, 1997 [22]	N/R	Yes	No	Yes	Yes	N/R	Yes	Yes
Olsson, 2005* [23]	N/R	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Rabadi, 2008 [25]	N/R	N/R	Yes	N/R	No	N/R	Yes	Yes
Rapport, 1993 [24]	Yes	N/R	No	Yes	Yes	N/R	Yes	No
Sze, 2001 [26]	N/R	N/R	Yes	N/R	Yes	No	Yes	Yes
Tilson, 2012 [27]	N/R	Yes	Yes	N/R	Yes	No	N/R	Yes

*This study aimed to validate an existing model but also derived a modified model. It was quality assessed as a derivation study.

Model development

Details of statistical analysis used in the studies to derive final models are presented in Table 2. The majority of studies categorised clinical measures before analysis, while two analysed all appropriate variables continuously.[12,24] Four studies presented information about missing values for important variables but none reported conducting imputations for these values.[12,13,26,27] Regression coefficients were reported in four studies.[12,13,24,26]

Table 2. Risk prediction model details

First author Year Outcome (no. with outcome)	**Regression method** **Multivariable analysis selection methods**	**Final Model(s)***	**Model Performance**[†]
Ashburn 2008 [12] Multiple falls (48)	Logistic p-value<0.15 in univariable analysis Forward selection	Model 1: 0.293 + 1.290 (if hospital near fall) - (0.094 x Rivermead upper limb), Cut-point: ≥ -0.4114 Model 2: -0.455 + 1.421(if hospital near fall) + (0.149 x Rivermead leg and trunk) - (0.119 x Rivermead upper limb) + (0.024 x BBS) - (0.046 x mean functional reach) - (0.012 x NEADL), Cut-point: ≥ −0.3731	AUC: 0.694 Sn/Sp: 60%/70% AUC: 0.712 Sn/Sp: 64%/69% R^2, HLT: N/R
Baetens 2011 [13] Any fall (38)	Logistic p-value<0.10 in univariable analysis Selected within MV analysis for effect on other OR estimates in model	General model: y = 3.21 (if FAC 3) –1.52 (if FAC 0–1–2) + 3.12 (if Star Cancellation Time >95 seconds) + 2.50 (if walking aid) + 1.28 (if unable to mobilise without 2 persons) - 2.22 Probability: $e^y/(1+e^y)$, Cut-point: 0.5 probability Mobility model: y =2.03 (if FAC 3) + 0.04 (if FAC 0-2) + 1.30 (if grip strength on unaffected side ≤0.55 bar) - 0.61 Probability: $e^y/(1+e^y)$, Cut-point: 0.5 probability	AUC: 0.87 95% CI(0.75, 0.94) R^2: 0.54 HLT: 0.89 (X^2=2.94-7 df) Sn/Sp: 94%/56% AUC: 0.743 95% CI(0.63, 0.86) R^2: 0.24 HLT: 0.84 (X^2=1.41-4 df) Sn/Sp: 76%/67%
Chen 2015 [28] No. of falls (15 fell)	Poisson Final model variables: p<0.1 in multivariable analysis	• Spatial neglect at admission (KF-NAP score >0) • Increased age (protective) (Combination score N/R)	R^2: 0.12 AUC, HLT: N/R Sn/Sp: N/R
Kerse 2008 [20] Any fall (407) Injurious fall (151)	Logistic p-value<0.2 in univariable analysis or apriori clinical judgement Backward selection	All falls model: Age at stroke, female sex, prestroke falls history, previous stroke, HMT>6 at 6 months, Barthel Index, 6 month depression (Combination score N/R) Injurious falls model: Female sex, NZ/European ethnicity, poor cognitive function, High Frenchay Activity Index, Premorbid dependency (protective) (Combination score N/R)	AUC: 0.62 AUC: 0.73 R^2, HLT: N/R Sn/Sp: N/R
Mackintosh 2006 [3] Multiple falls (12)	Logistic p-value<0.05 in univariable analysis Forward stepwise	Model 1: (BBS <49) and (fall as inpatient), "Yes" to both= at risk of repeat falling Model 2: (Step test <7) and (fall as inpatient), "Yes" to both= at risk of repeat falling	Sn/Sp: 83%/91% Sn/Sp: 83%/86% AUC, R^2, HLT: N/R

Nakagawa 2008 [21] Any fall (270)	Proportional hazards p-value<0.10 in univariable analysis	• Central paralysis= 1 • History of previous falls= 1 • Use of psychotropic medicines= 1 • Visual impairment = 1 • Urinary incontinence = 1 • Hasegawa's Dementia Scale Score 0–26=1 • Walks with walker= 1 or In wheelchair=2 Cut-point: >4	AUC: 0.73 Sn/Sp: 70%/69% R^2, HLT: N/R
Nyberg 1997 [22] Time to fall (49 fell)	Proportional hazards p-value<0.10 in univariable analysis Stepwise	• Male sex= 2 • Katz ADL score of E or lower =2 • Urinary incontinence=2 • FMA postural stability score <10/14 =1 • Motricity index <96/100 bilaterally = 1 • Visuospatial hemineglect =1 • Bilateral cortical and white matter lesions = 1 • Use of Diuretics, antidepressants, or sedatives = 1 Risk: Low= 0-4, Intermediate= 5-7, High= 8-11	AUC, R^2, HLT: N/R Sn/Sp: N/R
Olsson 2005 [23] Time to fall (39 fell)	Proportional hazards p-value<0.15 in univariable analysis Stepwise	Index follows an accumulated model: 1 point = FMA postural stability score <10/14 2 points = FMA postural stability score <10/14 +Visuospatial hemi-inattention 3 points= FMA postural stability score <10/14 +Visuospatial hemi-inattention +male sex	AUC, R^2, HLT: N/R Sn/Sp: N/R Hazard Ratio =1.9 95% CI (1.4-2.7)
Rabadi 2008 [25] Any fall (117)	Logistic Backward stepwise	• Mini Mental State Exam <25/30 • Ambulation speed <0.5m/s (Combination score N/R)	AUC, R^2, HLT: N/R Sn/Sp: N/R "Overall prediction": 68%
Rapport 1993 [24] Any fall (15) No. of falls	Regression type N/R p-value <0.05 on univariable analysis Stepwise	All falls model: 0.23 x (Falls Assessment Questionnaire) + 7.31 x (Failure to inhibit to left trials) - 0.34, Cut-point: >0.55 Number of falls model: 0.11 x (Falls Assessment Questionnaire) + 3.79 x (Failure to inhibit to left trials) - 0.11, Cut-point: >0.45	R^2: 0.66 Sn/Sp: 80%/82% R^2: 0.65 Sn/Sp: 80%/82% AUC, HLT: N/R
Sze 2001 [26] Any fall (78)	Logistic p-value<0.15 in univariable analysis Forward stepwise	Model 1: (Admission Barthel Index) and (Dysphasia) (Combination score N/R) Model 2: (Admission Barthel Index) and (Dysphasia type) (Combination score N/R)	HLT: p=0.5158 HLT: p=0.8736 AUC, R^2: N/R Sn/Sp: N/R
Tilson 2012 [27] Multiple or injurious falls (147)	Classification and Regression Tree (CART) method Twoing splitting rule	Single best predictor: BBS <43/56 Model reported to have poor generalisability‡: BBS, ABC, Alcohol Abuse, Age (Combination score N/R)	Single predictor: Sn/Sp: 73%/53% Model: AUC, R^2, HLT: N/R Sn/Sp: N/R

* FAC= Functional Ambulation Category, ADL= Activities of Daily Living, FMA= Brunnstrom Fugl-Meyer Assessment, KF-NAP= Kessler Foundation Neglect Assessment Process, BBS= Berg Balance Scale, HMT= Hodkinson Mental Test, NEADL= Nottingham Extended Activities of Daily Living, ABC= Activity-specific Balance Confidence Scale
† Sn/Sp= Sensitivity/ Specificity, AUC= Area Under the Curve/ C-Statistic, CI= Confidence Intervals, N/R= Not reported, HLT= Hosmer-Lemshaw Test,
‡ Details of model obtained from author correspondence

Model performance

Model calibration (goodness of fit between prediction and observation) was reported using results from the Hosmer-Lemeshow test in two studies.[13,26] Discrimination was summarised with the C-statistic (AUC) for seven models in four studies.[12,13,20,21] Values ranged from 0.62 [20] to 0.87.[13] Only one study presented 95% confidence intervals for the AUC.[13] Overall model performance was summarised using the R2 value (explained variance) in three of the studies. [13,24,28] The three studies that used proportional hazards regression analysis presented risk groups on Kaplan Meier graphs with significant log rank statistics.[21-23]

Model evaluation

Only one study reported conducting broad validation.[23] Nyberg and colleagues' original model was found to have good sensitivity (97%) but poor specificity (26%) in a new validation cohort studied in the same setting six years later.[22,23] Olsson and colleagues produced a re-modelled score and found it to be significantly associated with falls-risk in the original cohort (Hazard ratio= 1.8, 95%CI 1.4-2.4).[23] Tilson and colleagues carried out ten-fold cross-validation to prevent over-fitting of their model. Although their multivariable model showed better prediction accuracy than the Berg Balance Score alone within the original cohort, it had poor generalisability with validation.[27]

Predictors included in models

The majority of studies provided reproducible descriptions of valid outcome measures used to define their important predictors.[3,12,13,22-26,28] In the inpatient setting, the most common predictor incorporated into final prediction models was neglect/ hemi-inattention, present in three studies.[22,23,28] Although several predictors were common to two studies in the inpatient setting, there was minimal overlap in definitions, with the exception of the study that aimed to validate a previous model.[23] In the community setting the predictors most commonly included in the final risk prediction model were falls (or near-falls) history and balance, each identified in three studies.[3,12,20,27] Balance was measured using the Berg Balance Scale in all three studies, however differences arose in how the variable was treated in analysis.[3,12,27] Please see Supplemental Table III (online only) for adjusted effect measures of predictors in the original analyses.

DISCUSSION

This is the first systematic review to summarise the totality of evidence in relation to falls-risk prediction models early after stroke. Models with two purposes have been identified: models intended for the short-term prediction of falls within the inpatient setting post-stroke, and models intended to predict falls in the longer term among stroke survivors being discharged home. Methodological quality was variable overall. The two risk prediction models that met most quality criteria included measures of physical function, stability and hemi-inattention.[13,23] Only four out of twelve studies reported C-statistics, with only one model reporting a value of >0.8, indicating good discrimination.[13,30] As only one author reported 95% confidence intervals for C-statistics, and the values were wide, it was not possible to directly compare performance of models.[13] Only two studies reported validation, a critical step for model evaluation.[14,23,27]

A variety of fall outcome definitions were found across studies. Within the inpatient setting, the majority of studies focused on the occurrence or timing of the first fall.[21-23,25] With shorter follow-up time periods in this setting, it may have been difficult to account for multiple fall events. In addition, time to first fall may have been easier to record accurately than in the community setting, as falls are frequently noted by nursing staff routinely.[1] Disagreement about outcome was observed among community studies. Baetens and colleagues argue that the prediction of any fall is important because one fall can have serious consequences.[13] In contrast, two studies chose to predict repeat falls, explaining that this outcome is more likely to lead to injury and activity restriction.[3,12] The remaining studies differentiated between injurious and non-injurious falls.[20,27] This disagreement has been observed previously in falls prevention research among older adults.[31] A consensus group recommended that all outcomes including rate, faller categories and time to first fall should be reported, but that analysis should account for multiple events within individuals.[31] These recommendations may be relevant to falls prediction after stroke but this has not yet been established.

The time-point at which data was collected to derive prediction models varied across included studies. This was defined by some in terms of time since stroke,[20,22,23,25-27] or alternatively by a service transition including rehabilitation admission [13,21,24] or discharge.[3,12] In order to minimise heterogeneity, studies were excluded where the majority of participants were measured after three months since stroke. The majority of motor and functional gains are made within this phase of stroke recovery and so prediction at variable time-points may be difficult.[16] A systematic review of prognostic studies for functional outcomes suggested that participants should be tested at defined time-points early after stroke to aid recovery prediction.[32] Acknowledging this, the decision to implement falls prevention measures may be more clinically relevant at the point of a service transition.[12]

The complexity of algorithms has been cited as a barrier to clinical application of prognostic models within stroke rehabilitation.[32] Seven of the included studies in the review provided a formula from which falls-risk could be calculated,[3,12,13,21-24] while four of these provided a simplified score.[3,21-23] The categorisation of continuous predictors has been justified in several previous prognostic studies, citing the need for clinical simplicity and to avoid assumptions about linear relationships.[33,34] Recent guidelines strongly caution against discarding information through dichotomisation, and instead advise carrying out non linear transformations where indicated.[15,17] Only two studies in this review analysed appropriate variables continuously.[12,24] The successful translation of prognostic models into clinical practice is not yet well understood and warrants further investigation.[14]

As none of the included studies presented a validated model with acceptable performance, further research is required before clinical impact can be assessed. Poor reporting was found in several areas, which could hinder the validation and updating of models. Few studies reported standard performance measures with 95% confidence intervals making comparison difficult. Regression coefficients, necessary for model updating were also rarely reported.[35] This trend of poor reporting has been observed in several other systematic reviews in stroke and other fields.[14,32] For this reason, the Transparent Reporting of a multivariable prediction model for Individual Prognosis Or Diagnosis (TRIPOD) guidelines were recently developed to standardise the conduct and reporting of this research.[15]

Strengths and limitations of the review

This review was carried out using a robust methodology with reference to MOOSE and PRISMA guidelines, and up-to-date guidance from the Cochrane Prognosis Methods Group.[17,36,37] There are however some points to consider when interpreting the results of this review.

The CHARMS checklist was recently published to aid data extraction for systematic reviews of prognostic model studies.[17] Although early versions of this checklist have been used in previous reviews, it is not a formal risk of bias assessment tool.[32] At the time of writing, the Cochrane Prognosis Methods group are in the final stages of developing PROBAST (Prediction study Risk Of Bias Assessment Tool), which should fulfil this function.[38] A pragmatic approach was therefore taken to quality assessment within this review by using a short tool based on the McGinn criteria.[18] The CHARMS checklist was used to ensure complete data extraction and to highlight additional points of quality.[17]

While this review details the variables that were included in predictive models, we did not aim to identify modifiable risk factors for falling in this population. Previous systematic reviews of prognostic studies have included a variety of studies that focus on both individual risk factors and multivariable models.[32,39] In contrast, this review focuses on prognostic model studies as defined by the Cochrane Prognosis Methods Group, with the aim of identifying models that require validation and impact measurement.[14,17] Due to the similarity in methodology between studies focusing on independent risk factors/predictors and those aiming to build a prediction model, we have made their details available in the Online Supplementary Material.

Clinical and research Implications

This review is a key step in the process of developing falls-risk prediction models that can be incorporated into stroke rehabilitation to aid clinical decision-making. The findings will facilitate researchers and clinicians to identify important prognostic factors, and standardise predictor assessment, in order to validate existing models.[17] Only when models have been broadly validated can we consider the clinical impact of identifying potential fallers both in an inpatient and community setting.[14] Risk-stratification may also improve trials of falls-prevention interventions in the stroke population, which have not yet shown effectiveness.[14,40]

CONCLUSION

Several risk prediction models for falling have been developed for use in the acute and sub-acute stages of stroke. Further research should focus on validating and improving existing models, with reference to the TRIPOD guidelines to ensure quality reporting.

Contributors

All authors were involved in study design, interpretation, manuscript review and final approval of the paper. In addition, MW conducted study selection, data extraction and quality appraisal and prepared the first draft of the manuscript. FH provided clinical advice. CW provided statistical advice. RG conducted study selection, data extraction and quality appraisal.

Funding

Funding was received from the Irish Research Council (Government of Ireland Postgraduate Scholarship Scheme 2013).

Competing Interest

None declared.

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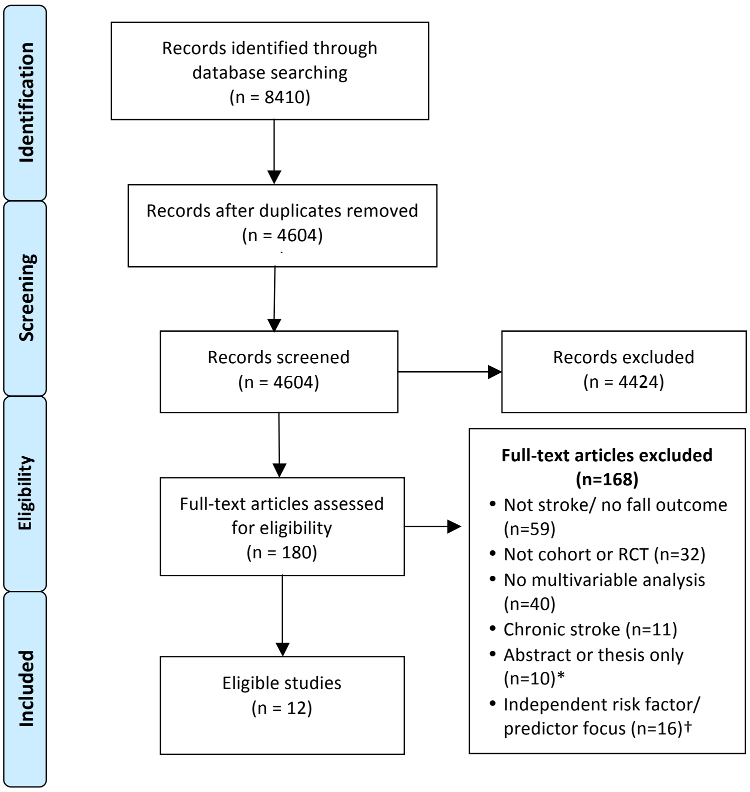

* Authors contacted for publication status of work. Only published journal articles were included

† Please see Supplemental Table I for details

Figure 1. Flow diagram of literature search

ONLINE ONLY SUPPLEMENTARY MATERIAL

A systematic review of risk prediction models for falls after stroke

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3. Discipline of Physiotherapy, Department of Clinical Therapies, Faculty of Education and Health Sciences, University of Limerick, Ireland

Supplemental Methods

OVID MEDLINE Search String

1 Risk Assessment/mt [Methods]
2 models, statistical/
3 forecasting/
4 Risk/
5 "risk".mp
6 4 OR 5
7 score.mp
8 6 AND 7
9 Risk Factors/
10 "risk".mp
11 "factor*".mp
12 10 ADJ 11
13 "risk factors".mp
14 "Predictive Value of Tests"/
15 "Sensitivity and Specificity"/
16 "predict*.mp"
17 1 OR 2 OR 3 OR 8 OR 9 OR 12 OR 13 OR 14 OR 15 OR 16
18 Cerebrovascular Disorders/
19 Stroke/
20 exp Basal Ganglia Cerebrovascular Disease/
21 exp Brain Ischemia/
22 exp Brain Infarction/
23 exp Intracranial Hemorrhages/
24 (stroke OR poststroke OR post-stroke OR cerebrovasc* OR CVA)
25 (brain) ADJ5 (vasc*).mp.
26 (cerebral) ADJ5 (vasc*).mp
27 Hemiplegia/
28 exp paresis/
29 (hemipleg* OR hemipar* OR paresis OR paretic).mp.
30 18 OR 19 OR 20 OR 21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29
31 accidental falls/
32 accidents/
33 exp accident prevention/
34 accidents, home/
35 accident proneness/
36 (fall OR falls OR faller OR fallen OR fallers OR falling OR "fall-related" OR "near-fall" OR "falls-efficacy scale").mp.
37 (slip OR slips OR slipped OR slipping OR trip OR trips OR tripped OR tripping).mp.
38 (stumble* OR tumble*).mp.
39 31 OR 32 OR 33 OR 34 OR 35 OR 36 OR 37 OR 38
40 17 AND 30 AND 39

	EMBASE Search String
1	"Risk Assessment"/de
2	"statistical model"/de
3	"forecasting"/de
4	"prediction"/de
5	Risk/de
6	"risk"
7	5 OR 6
8	"score"
9	7 AND 8
10	"Risk Factor"/de
11	"risk"
12	factor*
13	11 ADJ 12
14	"risk factors"
15	"Predictive Value"/de
16	"Sensitivity and Specificity"/de
17	predict*
18	1 OR 2 OR 3 OR 4 OR 9 OR 10 OR 13 OR 14 OR 15 OR 16 OR 17
19	Cerebrovascular Disease/de
20	Cerebrovascular Accident /de
21	'Brain Ischaemia'/exp
22	'Brain Infarction'/exp
23	'Brain Hemorrhage'/exp
24	"stroke" or "poststroke" or "post-stroke" or cerebrovasc* or "CVA"
25	"brain" ADJ5 vasc*
26	"cerebral" ADJ5 vasc*
27	"Hemiplegia"/de
28	paresis/exp
29	hemipleg* or hemipar* or "paresis" or "paretic"
30	19 OR 20 OR 21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29
31	"falling"/de
32	"accident"/de
33	"accident prevention"/exp
34	"home
35	"accident proneness"/de
36	"fall" OR "falls" OR "faller" OR "fallen" OR "fallers" OR "falling" OR "fall- related" OR "near-fall" OR "falls-efficacy scale"
37	"slip" OR "slips" OR "slipped" OR "slipping" OR "trip" OR "trips" OR "tripped" OR "tripping"
38	stumble* OR tumble*
39	31 OR 32 OR 33 OR 34 OR 35 OR 36 OR 37 OR 38
40	18 AND 30 AND 39

CINAHL on EBSCO Search String

1	MH "Fall Risk Assessment Tool")
2	(MH "Models, Statistical")
3	(MH "Forecasting (Research)")
4	(MH "Predictive Research")
5	risk
6	score
7	5 AND 6
8	(MH "Risk Assessment")
9	(MH "Risk Factors")
10	risk
11	factor*
12	10 W1 11
13	"risk factors"
14	(MH "Predictive Value of Tests")
15	(MH "Sensitivity and Specificity")
16	predict*
17	1 OR 2 OR 3 OR 4 OR 7 OR 8 OR 9 OR 12 OR 13 OR14 OR 15 OR 16
18	(MH "Cerebrovascular Disorders")
19	(MH "Stroke")
20	(MH "Basal Ganglia Cerebrovascular Disease+")
21	(MH "Cerebral Ischemia")
22	(MH "Intracranial Hemorrhage+")
23	"stroke" OR "poststroke" OR "post-stroke" OR cerebrovasc* OR CVA
24	"brain" N5 vasc*
25	"cerebral" N5 vasc*
26	(MH "Hemiplegia")
27	hemipleg* OR hemipar* OR "paresis" OR "paretic"
28	18 OR 19 OR 20 OR 21 OR 22 OR 23 OR 24 OR 25 OR 26 OR 27
29	(MH "Accidental Falls")
30	(MH "Accidents")
31	(MH "Accidents, Home")
32	"fall" OR "falls" OR "faller" OR "fallen" OR "fallers" OR "falling" OR "fall- related" OR "near-fall" OR "falls-efficacy scale"
33	"slip" OR "slips" OR "slipped" OR "slipping" OR "trip" OR "trips" OR "tripped" OR "tripping"
34	stumble* OR tumble*
35	29 OR 30 OR 31 OR 32 OR 33 OR 34
36	17 AND 28 AND 35

OVID PsycINFO Search String

1	risk assessment/
2	prediction/
3	Risk Factors/
4	risk.mp.
5	factor*.mp.
6	score.mp.
7	4 ADJ 5
8	4 AND 6
9	"risk factors".mp.
10	predict*.mp.
11	1 OR 2 OR 3 OR 7 OR 8 OR 9 OR 10
12	Cerebrovascular Disorders/
13	exp Cerebral Ischemia/
14	Cerebrovascular Accidents/
15	exp Cerebral Hemorrhage/
16	(stroke OR poststroke OR "post-stroke" OR cerebrovasc* OR "cva").mp
17	brain ADJ5 vasc*
18	cerebral ADJ5 vasc*
19	Hemiplegia/
20	hemiparesis/
21	(hemipleg* OR hemipar* OR paresis OR paretic).mp
22	12 OR 13 OR 14 OR 15 OR 16 OR 17 OR 18 OR 19 OR 20 OR 21
23	Accidents/
24	Falls/
25	exp Accident Prevention/
26	Home Accidents/
27	Accident Proneness/
28	("fall" OR "falls" OR "faller" OR "fallen" OR "fallers" OR "falling" OR "fall- related" OR "near-fall" OR "falls-efficacy scale").mp.
29	("slip" OR "slips" OR "slipped" OR "slipping" OR "trip" OR "trips" OR "tripped" OR "tripping").mp.
30	(stumble* OR tumble*).mp.
31	23 OR 24 OR 25 OR 26 OR 27 OR 28 OR 29 OR 30
32	11 AND 22 AND 31

Web of Science Search String

1	TS=(risk NEAR/1 factor*)
2	TS=(risk AND score)
3	TS=("risk factors")
4	TS=(predict*)
5	TS=("risk assessment")
6	#5 OR #4 OR #3 OR #2 OR #1
7	TS=(stroke)
8	TS=(poststroke)
9	TS=("post-stroke")

10 TS=(cerebrovasc*)
11 TS=(brain NEAR/5 vasc*)
12 TS=(cerebral NEAR/5 vasc*)
13 TS=(hemipleg*)
14 TS=(hemipar*)
15 TS=(paresis)
16 TS=(paretic)
17 TS=((intracranial OR brain) NEAR/1 h$emorrhage)
18 TS=((cerebral OR brain) NEAR/3 isch$emia)
19 TS=((cerebral OR brain) NEAR/3 infarction)
20 TS=(cva)
21 #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 OR #14 OR #15 OR
22 TS=(fall) OR TS=(falls) OR TS=(faller) OR TS=(fallen) OR TS=(fallers) OR TS=(falling) OR TS=(fall-related) OR TS=(near-fall) OR TS=(falls-efficacy scale)
23 TS=(slip) OR TS=(slips) OR TS=(slipped) OR TS=(slipping) OR TS=(trip) OR TS=(trips) OR TS=(tripped) OR TS=(tripping).
24 #22 AND #23
25 #6 AND #21 AND #24

Cochrane Library Search String

1 MeSH descriptor: [Risk Assessment] explode all trees and with qualifier(s): [Methods - MT]
2 MeSH descriptor: [Models, Statistical] this term only
3 MeSH descriptor: [Forecasting] this term only
4 MeSH descriptor: [Risk] this term only
5 risk
6 score
7 #4 OR #5
8 #7 AND #6
9 MeSH descriptor: [Risk Factors] this term only
10 factor*
11 #5 NEXT #10
12 "risk factors"
13 MeSH descriptor: [Predictive Value of Tests] this term only
14 MeSH descriptor: [Sensitivity and Specificity] this term only
15 predict*
16 #1 or #2 or #3 or #8 or #9 or #11 or #12 or #13 or #14 or #15
17 MeSH descriptor: [Cerebrovascular Disorders] this term only
18 MeSH descriptor: [Stroke] this term only
19 MeSH descriptor: [Basal Ganglia Cerebrovascular Disease] explode all trees
20 MeSH descriptor: [Brain Ischemia] explode all trees
21 MeSH descriptor: [Brain Infarction] explode all trees
22 MeSH descriptor: [Intracranial Hemorrhages] explode all trees
23 stroke OR poststroke OR "post-stroke" OR cerebrovasc* OR (brain NEXT vasc*) OR (cerebral NEXT vasc*)
24 MeSH descriptor: [Hemiplegia] this term only

25 MeSH descriptor: [Paresis] explode all trees
26 hemipleg* OR hemipar* OR paresis OR paretic
27 #17 OR #18 OR #19 OR #20 OR #21 OR #22 OR #23 OR #24 OR #25 OR #26
28 MeSH descriptor: [Accidental Falls] this term only
29 MeSH descriptor: [Accidents] this term only
30 MeSH descriptor: [Accident Prevention] explode all trees
31 MeSH descriptor: [Accidents, Home] this term only
32 MeSH descriptor: [Accident Proneness] this term only
33 "fall" OR "falls" OR "faller" OR "fallen" OR "fallers" OR "falling" OR "fall- related" OR "near-fall" OR "falls-efficacy scale"
34 slip OR slips OR slipped OR slipping OR trip OR trips OR tripped OR tripping
35 stumble* OR tumble*
36 #28 OR #29 OR #30 OR #31 OR #32 OR #33 OR #34 OR #35
37 #16 AND #27 AND #36

Scopus Search String

(TITLE-ABS-KEY ((risk PRE/1 factor*) OR (risk AND score) OR "risk factors" OR predict* OR "risk assessment")) AND (TITLE-ABS-KEY(stroke OR poststroke OR "post-stroke" OR cerebrovasc* OR (brain W/5 vasc*) OR (cerebral W/5 vasc*) OR ((intracranial OR brain) PRE/1 h*morrhage) OR ((cerebral OR brain) W/3 isch*mia) OR ((cerebral OR brain) W/3 infarction) OR "cva" OR hemipleg* OR hemipar* OR paresis OR paretic)) AND (TITLE-ABS KEY (fall OR falls OR faller OR fallen OR fallers OR falling OR "fall-related" OR "near-fall" OR "falls-efficacy scale" OR slip OR slips OR slipped OR slipping OR trip OR trips OR tripped OR tripping OR stumble* OR tumble*))

Guidance notes for methodological quality appraisal

These guidance notes were developed by the authors (RG, MW) apriori, with reference to McGinn et al.[1]

Score each item as either Yes/No/Not Reported

Internal validity

1. *Were those assessing the outcome event blinded to presence of predictors?*

   The presence or absence of an outcome event should be determined without knowledge of the status of predictor variables. If the study did not comment on the blinding process then record as 'not reported'. If the outcome was not dependant on blinding (e.g. death), then record as' yes'.

2. *Were those assessing the presence of predictors blinded to the outcome event?*

   If the study is prospective and predictor variables were collected prior to the outcome event then assessment is considered to be blind. If the study is conducted retrospectively, this should be coded as appropriate i.e. need a clear comment on the blinding process.

3. *Adequate sample size (including outcome events)?*

   There should be at least 10 falls per independent variable in the final prediction rule to be considered adequate. For example, a prediction rule with 4 variables should have 40 falls.

4. *Clinically sensible?*

   The rule should display content validity i.e. most clinicians should think that the items in the prediction rule seem clinically sensible and no obvious items are missing. Furthermore, the methods of aggregating the components should seem reasonable and the variables should seem appropriate for the purpose of the rule.

External Validity

1. *Were all important predictors included in the derivation process?*

   The authors identified a number of variables believed to predict the occurrence of the outcome (univariable analysis/descriptive analysis reported). There should be no obvious predictors missing during the derivation process. Studies that examined at least one factor from at least three of the following categories (stroke-related, general health, demographic, physical function) will be considered to have measured important predictors.

2. *All important predictors present in a significant proportion of the study population?*

   Are predictors present in minimum of 5% of population? Important predictors are those defined by primary study authors based on clinical judgement or univariable analysis.

3. *All predictors and outcome events clearly defined?*

a. Predictors should be defined in a clear, clinically sensible and reproducible manner. They should be valid outcome measures, include a clear description of administration and a clear description of the scoring system/ rating scale.
b. The outcome being predicted by the rule should be clearly defined – That, is to allow the reader to understand the definition and be able to replicate it in their own setting. There should be a clear and explicit definition of a fall.

Supplemental Table I. Multivariable analyses from studies excluded from final review

First author Year (model)	N	Setting of fall*	Fall outcome (number)	Variables included in multivariable analysis[†]	Effect measure[‡]	Adjusted value[§]	95% CI[§]
Chin [2] 2013	126	Com	Any fall (30)	FIM Transfer FIM Bladder and Bowel FIM Mobility FIM Communication FIM Social Cognition Length of stay Lower limb Fugl-Meyer Berg Balance Scale (BBS)	OR	0.78 N/R N/R N/R N/R N/R N/R N/R	0.62, 0.99 N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig)
Czernuszenko [3] 2009 (Single fall outcome)	1155	Inp	Time to first fall (189)	Barthel Index <15/20 Onset-to-admission <12 weeks Presence of neglect Age >65 years Left-sided motor deficit Scandinavian Stroke Scale <46/48	HR	5.19 2.33 1.49 N/R N/R N/R	2.48, 10.86 1.38, 3.94 1.02, 2.19 N/R (not sig) N/R (not sig) N/R (not sig)
Czernuszenko [3] 2009 (Multiple falls outcome)	1155	Inp	Time to second fall (63)	Barthel Index <15/20 Onset-to-admission <12 weeks Age >65 years Presence of neglect Scandinavian Stroke Scale <46/48	HR	4.55 2.29 1.43 N/R N/R	2.16, 9.6 1.33, 3.96 1.06, 1.9 N/R (not sig) N/R (not sig)
Jalayondeja [4] 2014 (One month measures)	97	Com	Any fall (25)	FES >32/100† Barthel Index <83/100[#] Preferred gait speed <=0.4m/s[#] 2MWT <=34 metres[#] Max gait speed<=0.6m/s[#] BBS <43/56[#] TUG >=14 seconds† Age Sex BMI Cognition (Thai MMSE)	OR	2.79 2.17 1.42 1.41 1.38 1.27 0.97 N/R N/R N/R N/R	0.95, 8.28 0.76, 6.18 0.47, 4.26 0.46, 4.32 0.45, 4.28 0.41, 3.92 0.26, 3.58 N/R N/R N/R N/R

First author Year (model)	N	Setting of fall*	Fall outcome (number)	Variables included in multivariable analysis†	Effect measure‡	Adjusted value§	95% CI§
Jalayondeja [4] 2014 (Three month measures)	97	Com	Any fall (25 fell in 6m)	Barthel Index <83/100# 2MWT <=34 metres# FES >32/100# TUG Max gait speed <=0.6m/s# BBS <43/56# Preferred gait speed <=0.4m/s# Age Sex BMI Cognition (Thai MMSE)	OR	4.69 4.15 4.1 3.99 3.64 3.27 2.13 N/R N/R N/R N/R	1.44, 15.27 1.23, 14.06 1.19, 14.07 1.00, 15.96 1.03, 12.81 1.00, 11.34 0.65, 6.96 N/R N/R N/R N/R
Forster [5] 1995	108	Com	Multiple (51)	Falls in hospital Sex Age Co-morbidities Mental state test score Albert's test (neglect) Proprioception (pass/fail) Time to walk 5 metres Living alone/ with carer Barthel index Nottingham health profile Motor club assessment	OR	2.0 N/R N/R N/R N/R N/R N/R N/R N/R N/R N/R N/R	1.2, 3.5 N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig)
Mansfield [6] 2012	100	Inp	Any fall (20)	Force plate–based measures: • Anteroposterior synchronisation • Root mean square of mediolateral centre of pressure • Stance load symmetry	OR	 0.10 1.3 1.1	 0.01, 0.91 1.0, 1.6 1.0, 1.3
Mayo [7] 1990	202	Inp	Any fall (95)	Response time to visual stimulus: • 0.00-0.49 seconds • 0.50-0.99 seconds • 1.0-1.49 seconds • 1.5-1.99 seconds • 2.0-2.49 seconds • >=2.5 seconds Depression Age Male sex History of previous stroke Side of lesion, left Visual hemineglect	OR**	 Reference 1.09 2.00 3.11 6.67 2.74 1.75 1.12 1.38 1.34 1.28 1.47	 Reference 0.44, 2.68 0.63, 6.38 1.01, 9.63 1.49, 29.79 1.04, 7.17 1.00, 3.75 0.89, 1.42 0.78, 2.41 0.63, 2.85 0.73, 2.27 0.75, 2.88

First author Year (model)	N	Setting of fall*	Fall outcome (number)	Variables included in multivariable analysis	Effect measure‡	Adjusted value§	95% CI§
Minana-Climent [8] 2005	1410	Inp	Any fall (115)	Delirium	OR	4.69	2.93, 7.51
				Depression		1.76	1.10, 2.83
				Arm strength (MRC)		1.23	1.06, 1.44
				Previous Barthel Index		1.01	1.00,1.02
				Age		0.96	0.93, 0.99
				Stroke severity (OPS <3)		0.35	0.15, 0.78
				Stroke severity (OPS 3-5)		1.15	0.66, 2.00
				Leg strength (MRC)		N/R	N/R (not sig)
				Level of consciousness		N/R	N/R (not sig)
				Dysphagia		N/R	N/R (not sig)
Nyberg [9] 1996	135	Inp	No. of falls (53 fell)	Downton Index sum	N/R	N/R	N/R (sig)
				Observation time in weeks		N/R	N/R
Nystrom [10] 2013	68	Both	Any fall (14)	Predict FIRST >2 points	OR	5.21	1.10, 24.78
				M-MAS UAS-99 C–E (transfer/ gait)		0.65	0.44, 0.95
				M-MAS UAS-99 A–B (bed mobility		1.78	0.94, 3.39
				M-MAS UAS-99 F–H (arm function)		1.11	0.90, 1.37
				No. of days in stroke unit		1.09	0.99, 1.20
Persson [11] 2011	96	Com	Any fall (46)	Age	OR	N/R	N/R (not sig)
				Sex		N/R	N/R (not sig)
				SwePASS <33/36#		4.88	2.02, 11.80
				MMAS UAS-95 <51/55#		3.71	1.67, 8.25
				10MWT >12 seconds#		3.17	1.54, 6.54
				BBS <43/56#		3.14	1.44, 6.86
				TUG >15 seconds#		2.44	1.22, 4.92
Persson [11] 2011 (General estimated equation analysis)	96	Com	Any fall (46)	Age	OR	N/R	N/R (not sig)
				Sex		N/R	N/R (not sig)
				Length of stay		1.04	1.01, 1.08
				SwePASS <33/36#		2.984	1.15, 7.74
				10MWT >12 seconds#		N/R	N/R (not sig)
				BBS <43/56#		N/R	N/R (not sig)
				M-MAS UAS-95 <51/55#		N/R	N/R (not sig)
				TUG >15 seconds#		N/R	N/R (not sig)
Schmid [12] 2010	1269	Inp	Any fall (65)	History of anxiety	OR	4.90	1.70, 13.90
				Stroke severity (NIHSS >7)		3.63	1.46, 9.00
				Charlson Comorbidities index		N/R	N/R (not sig)
				History of urinary tract infection		N/R	N/R (not sig)
				Gait abnormalities		N/R	N/R (not sig)

First author Year (model)	N	Setting of fall*	Fall outcome (number)	Variables included in multivariable analysis	Effect measure‡	Adjusted value§	95% CI§
Simpson [13] 2011	80	Com	No. of falls (14 fell once, 26 fell multiple times)	• Berg Balance Scale • TUG • Age • Cognition (CCSE) • Balance Confidence (ABC) • Sex	IRR	0.91 0.96 1.03 1.10 N/R N/R	0.85, 0.98 0.91, 0.99 0.99, 1.06 0.99, 1.22 N/R (not sig) N/R (not sig)
Suzuki [14] 2005	256	Inp	Time to first fall (121 fell)	• FIM motor <65 • FIM cognitive <30 • Sex • Age	HR	N/R N/R N/R N/R	N/R (p<0.00) N/R (p=0.63) N/R (p=0.14) N/R (p=0.13)
Tanaka [15] 2010	41	Inp	Any fall (18)	• Impaired attention • Movement disorder • Sensory impairment	N/R	N/R N/R N/R	N/R (sig) N/R (not sig) N/R (not sig)
Tutuarima [16] 1997	720	Inp	No. of falls (104 fell once)	• Urinary incontinence • Mental decline • Heart disease • Psychotropic medications • Age 66-75 • Age 76-85 • Age >85 • Female sex • Confusional state	RR	2.3 1.6 1.6 0.5 0.7 0.6 0.6 0.9 1.3	1.3, 4.1 1.0, 2.4 1.0, 2.4 0.3, 0.8 0.4, 1.2 0.3, 1.0 0.3, 1.2 0.6, 1.3 0.8, 2.0
Yates [17] 2002	280	Com	Any fall (142)	• Motor Impairment • Motor + Sensory Impairments • Motor + Sensory + Visual Impairments	OR	2.2 3.1 2.4	1.05, 4.70 1.46, 6.79 1.05, 5.83

* Com= Community, Inp= Inpatient

† FIM= Functional Independence Measure, FES= Falls Efficacy Scale, 2MWT= Two minute walk test, BBS= Berg Balance Scale, TUG= Timed up and go test, BMI= Body Mass Index, MMSE= Mini Mental State Exam, MRC= Medical Research Council, OPS= Orpington Prognostic Scale, M-MAS UAS= Modified Motor Assessment Scale according to Uppsala University Hospital, SwePASS= Swedish Version of the Postural Assessment Scale for Stroke Patients , 10MWT= 10 metre walk test, NIHSS= National Institute of Health Stroke Scale, CCSE= Cognitive Capacity Screening Examination, ABC= Activities-specific Balance Confidence Scale

‡ OR= Odds Ratio, RR=Relative Risk, HR= Hazard Ratio, IRR= Incidence Rate Ratio

§ N/R= Not reported, (sig)= Reported as statistically significant at 95% confidence level but no values reported, (not sig)= Reported as not statistically significant at 95% confidence level but no values reported

\# Included in separate multivariable analysis, controlled for remaining variables

** Unadjusted odds ratios presented

Supplemental Table II. Characteristics of included studies

First author Year (Country)	Study design	Setting of assessment	Participant description	Specific exclusion criteria	Time from onset of stroke at baseline assessment	Setting of falls outcome	Duration of follow-up
Ashburn [18] **2008** **(United Kingdom)**	Prospective cohort	Home-based assessments within 2 weeks of hospital discharge	N=115 Age: Mean 70.2 (SD not reported) Gender: 62% Male	• Not independently mobile prior to stroke • Did not pass a test of gross cognitive function • Discharged to a nursing home	Range: 10–330 days Mean: 78.9 days (SD not reported)	Community	12 months (Diaries returned monthly)
Baetens [19] **2011** **(Belgium)**	Prospective cohort	5 rehabilitation centres	N=65 Age: Mean 64.6 (SD 15.0) Gender: 60% Male	• Not first stroke • Major musculoskeletal problems • A concurrent neurologic disorder • Mini-Mental State Examination < 18 • Unable to understand or follow instructions	Mean 9.4 weeks (SD 6.2) Median 7 weeks (IQR 10)	Inpatient and Community	6 months (Diaries returned monthly)
Chen [20] **2015** **(USA)**	Prospective cohort	Inpatient rehabilitation facility	N=108 Age: Mean 70.1 (SD 13.0) Gender: 44% Male	• Not first stroke • Not unilateral brain damage	Median 6 days (IQR 5)	Inpatient	Until discharge: Median 21 days
Kerse [21] **2008** **(New Zealand)**	Prospective cohort	Multiple settings 2002-2003	N=1104 Age: Mean 70.7 (SD 13.3) Gender: 49% Male	None reported	Less than 1 month	Community	6 months
Mackintosh [22] **2006** **(Australia)**	Prospective cohort	Home-based assessments after discharge from 3 rehabilitation centres	N=55 Age: Mean 68.1 (SD 12.8) Gender: 45% Male	• A concurrent neurologic disorder • A major orthopedic problem • An Orientation-Memory-Concentration test score >10 and no caregiver • Insufficient English-language skills	Mean 2.3 months (SD 1.6)	Community	6 months (Diaries returned every 2 weeks)
Nakagawa [23] **2008** **(Japan)**	Prospective cohort	17 convalescent rehabilitation wards 2004-2005	N=704 Age: Mean 69.7 (SD 12.1) Gender: 58% Male	None reported	Mean 40.4 days (SD 24.9)	Inpatient	Until discharge: Less than 3 months

First author Year (Country)	Study design	Setting of assessment	Participant description	Specific exclusion criteria	Time from onset of stroke at baseline assessment	Setting of falls outcome	Duration of follow-up
Nyberg [24] **1997** **(Sweden)**	Prospective cohort	Inpatient stroke rehabilitation unit of a geriatric clinic 1991-1992	N=135 Age: Mean 74.8 (SD 8.9) Gender: 51% Male	• Those completely immobile and bedridden throughout their entire stay	Approximately 2-4 weeks	Inpatient	Up to 56 days, Median 49 days
Olsson [25] **2005** **(Sweden)**	Prospective cohort	Inpatient stroke rehabilitation unit of a geriatric clinic 1997-1998	N=158 Age: Mean 76.4 (SD 8.6) Gender: 46% Male	• Those completely immobile and bedridden throughout their entire stay	Approximately 2-4 weeks	Inpatient	Up to 56 days, Median 34.5 days
Rabadi [26] **2008** **(USA)**	Retrospective cohort	An acute stroke rehabilitation unit 24 month period	N=754 Age: Mean 70 (SD 13) Gender: 48% Male	• Not first stroke • No neuroimaging corresponding to signs and symptoms • Hemorrhage within a brain tumor • Sudden onset of clinical signs and symptoms due to brain lesion other than vascular cause	Mean 12 days (SD 7)	Inpatient	Until discharge: Mean 17 days (SD 9)
Rapport [27] **1993** **(USA)**	Prospective cohort	Inpatient rehabilitation unit	N=32 Age: Mean 62.3 (SD 6.3) Gender: 100% Male	• Only right hemisphere unilateral strokes included	Median: 60 days (range: 22-140 days)	Inpatient	Until discharge: Mean 47.6 days
Sze [28] **2001** **(China)**	Retrospective cohort	A stroke rehabilitation unit 1995-1997	N=677 Age: 74% >=65 years Gender: 53% Male	• Patients who did not receive brain CT scan • Patient who were on Foley urethral catheters	Approximately 1 week after onset	Inpatient	Until discharge: (Approx 4-6 weeks)
Tilson [29] **2012** **(USA)**	Randomised Controlled trial	After discharge from 5 centres Setting not reported	N=408 Age: Mean 62.0 (SD 12.7) Gender: 55% Male	• No residual paresis • Unable to walk 10 feet with one person • Unable to follow a 3-step command • Self-selected walking speed of >0.8 m/s	Mean 63.8 days (SD 8.5)	Community	Mean 10.3 months (SD 2.1) (Diaries returned monthly)

Supplemental Table III. Multivariable analyses results from included studies

First author Year (model)	Fall outcome (number)	Variables included in multivariable analysis*	Effect measure†	Adjusted value‡	95% CI‡
Ashburn [18] 2008	At least 2 falls (48)	Hospital near falls	OR	4.14	1.57, 10.91
		Rivermead upper limb		0.89	0.78, 1.01
		Rivermead leg and trunk score		1.16	0.85, 1.59
		Berg Balance Scale		1.02	0.95, 1.10
		Mean functional reach		0.96	0.89, 1.03
		Nottingham extended ADL		0.99	0.95, 1.03
Baetens [19] 2011 (General model)	At least 1 fall (38)	Functional Ambulation Category	OR		
		• 4–5 Walks independently		Reference	Reference
		• 3 Walks with supervision		24.8	1.7, 363.9
		• 0-2 (nonfunctional or needs physical assistance		0.2	0, 2.4
		Use of walking aid			
		• No use of an aid		Reference	Reference
		• Uses walking aid		12.1	1.4, 102
		• Aid not applicable - unable to mobilise without 2 persons		3.6	0.2, 77.7
		Star Cancellation time >95 secs		22.7	3.1, 164.9
		Civil state		N/R	N/R
		Grip strength on unaffected side		N/R	N/R
Baetens [19] 2011 (Mobility model)	At least 1 fall (38)	Functional Ambulation Category	OR		
		• 4–5 Walks independently		Reference	Reference
		• 3 Walks with supervision		7.6	1.4, 42.1
		• 0-2 (nonfunctional or needs physical assistance		1	0.3, 3.6
		Grip strength on unaffected side ≤ 0.55 bar		3.7	1.1, 11.9
		Use of walking aid			
		• No use of an aid		N/R	N/R
		• uses walking aid		N/R	N/R
		• Aid not applicable because unable to mobilise without 2 persons		N/R	N/R
Chen [20] 2015	No of falls (15 fell)	Spatial neglect at admission (KF-NAP score >0)	IRR	7.38	0.82, 66.12
		Age		0.96	0.92, 0.99
		Right brain stroke		0.59	0.19, 1.82
		Days post stroke at admission		0.97	0.89, 1.07
		Admission FIM motor		0.98	0.94, 1.02
		Admission FIM cognitive		1.03	0.92, 1.15

First author Year (model)	Fall outcome (number)	Variables included in multivariable analysis*	Effect measure†	Adjusted value‡	95% CI‡
Kerse [21] 2008 (All falls model)	At least 1 fall (407)	Baseline Barthel Index Score	OR		
		• 20 (independent)		Reference	Reference
		• 10–19		1.72	1.25, 2.36
		• 0–9 (dependent)		2.09	1.40, 3.12
		Age at stroke		1.06	1.00, 1.12
		6 month normal cognition (Hodkinson Mental Test>6)		0.81	0.55, 1.18
		Fall in last year before stroke		1.6	1.19, 2.16
		Female		0.99	0.75, 1.32
		Previous stroke at baseline		1.16	0.83, 1.61
		6 month often feel sad/depressed		1.48	1.09, 2.01
		Frenchay Activities Index Score		N/R	N/R (not sig)
		Premorbid self care dependency		N/R	N/R (not sig)
		Ethnicity		N/R	N/R (not sig)
		Living at home at 6 months		N/R	N/R (not sig)
		Marital status		N/R	N/R (not sig)
		Drinks alcohol		N/R	N/R (not sig)
		Any psychotropic medication		N/R	N/R (not sig)
		Anti-platelet therapy		N/R	N/R (not sig)
Kerse [21] 2008 (Injurious falls model)	Injurious fall (151)	Pre-morbid dependency	OR	0.46	0.26, 0.82
		6 month Frenchay Activities Index		0.8	0.72, 0.89
		Age at stroke		1.07	0.97, 1.17
		New Zealand/European ethnicity		1.94	1.11, 3.41
		Fall in year before stroke		1.33	0.89, 2.00
		Female		1.75	1.15, 2.64
		Previous stroke at baseline		1.52	0.98, 2.35
		6 month normal cognition (Hodkinson Mental Test >6)		0.53	0.32, 0.86
		Barthel Index score		N/R	N/R (not sig)
		Have tertiary qualifications		N/R	N/R (not sig)
		Living at home at 6 months		N/R	N/R (not sig)
		Marital status		N/R	N/R (not sig)
		Ever had atrial fibrillation		N/R	N/R (not sig)
		Drinks alcohol		N/R	N/R (not sig)
		Any anti-platelet therapy		N/R	N/R (not sig)
		Any psychotropic medication		N/R	N/R (not sig)
		Often feels sad or depressed at 6 months		N/R	N/R (not sig)
Mackintosh [22] 2006	At least 2 falls (12)	Berg Balance Scale <49§	OR	7.5	1.4, 40.6
		Fall in hospital or rehabilitation (Adjusted for Berg Balance Scale)		20.5	2.2, 190.6
		Step test <7§		9.7	1.0, 93.3
		Fall in hospital or rehabilitation (Adjusted for Step test)		17.2	1.9, 145.2
		Fast gait speed <0.56m/s§		N/R	N/R (not sig)
		Quadriceps strength§		N/R	N/R (not sig)

First author Year (model)	Fall outcome (number)	Variables included in multivariable analysis*	Effect measure†	Adjusted value‡	95% CI‡
Nakagawa [23] 2008	At least 1 fall (270)	Presense of central paralysis	HR		
		• Neither		Reference	Reference
		• Right		2.22	1.22, 4.02
		• Left		2.25	1.24, 4.08
		• Both		2.21	1.08, 4.52
		History of previous falls		1.73	1.25, 2.4
		Use of psychotropic medicines		1.31	1.02, 1.69
		Mode of locomotion:			
		• Walks with walker		2.48	1.14, 5.38
		• In wheelchair		2.96	1.6, 5.47
		Urinary incontinence		1.58	1.12, 2.22
		Revised Hasegawa's Dementia Scale Score 0–26		1.59	1.12, 2.61
		Visual impairment		1.33	0.99, 1.8
		Apraxia		1.32	0.89, 1.95
		Attention disturbance		1.11	0.82, 1.51
		Fecal incontinence		0.73	0.51, 1.03
		Delerium		1.74	0.65, 1.26
		Unilateral spatial neglect		0.84	0.60, 1.17
		Pain		1.13	0.86, 1.48
		Sensory disturbance		1.10	0.83, 1.47
Nyberg [24] 1997	Time to first fall (49 fell)	Male sex	OR‖	2	N/R (not sig)
		Katz ADL score of E or lower		2	N/R (not sig)
		Urinary incontinence		2	N/R (not sig)
		Postural stability score <10/14		1	N/R (not sig)
		Bilateral signs of hemiplegia		1	N/R (not sig)
		Visuospatial hemineglect		1	N/R (not sig)
		Bilateral brain lesions		1	N/R (not sig)
		Use of diuretics, antidepressants, or sedatives		1	N/R (not sig)
		Cognitive impairment (MMSE<24)		N/R	N/R
		Dyspraxia		N/R	N/R
		High white blood cell count		N/R	N/R
		High blood glucose level		N/R	N/R
Olsson [25] 2005	Time to first fall (39 fell)	Postural stability score <10/14	HR#	4.50	1.1, 18.7
		Visuospatial hemi-inattention		2.57	1.2, 5.4
		Male sex		1.65	0.9, 3.1
		Katz ADL score of E or lower		2.56	0.8, 8.4
		Bilateral brain lesions		0.54	0.3, 0.5
Rabadi [26] 2008	Any fall (117)	MMSE <25	OR	N/R	N/R (p<.001)
		Gait speed <0.5m/s		N/R	N/R (p=.004)
		Berg Balance Scale		N/R	N/R (not sig)
		Lower Extremity Motricity Index		N/R	N/R (not sig)
		Limb placement task		N/R	N/R (not sig)
		Visual impairments		N/R	N/R (not sig)

First author Year (model)	Fall outcome (number)	Variables included in multivariable analysis*	Effect measure†	Adjusted value‡	95% CI‡
Rapport [27] 1993	Any fall (15) No of falls	Falls Assessment Questionairre Failure to inhibit to left trials Rey-Osterreith Complex Figure Drawing (visuospatial) Digit span reverse (attentional)	N/R	N/R N/R N/R N/R	N/R N/R N/R N/R
Sze [28] 2001	At least 1 fall (78)	Admission Barthel Index (5-15/20) Dysphasia§ Expressive dysphasia§ Urinary incontinence on admission IHD Hemiplegia	OR	2.64 1.81 2.04 N/R N/R N/R	1.26, 5.51 1.03, 3.17 1.11, 3.79 N/R (not sig) N/R (not sig) N/R (not sig)
Tilson [29] 2012**	Multiple/ Injurious falls (147)	Berg Balance Scale ABC scale Age Alcohol abuse Total Motor Fugl-Meyer Lower limb Fugl-Meyer Upper limb Fugl-Meyer Comfortable walking speed Fast walking speed 6-minute walk distance Use of assistive device Stroke impact scale Modified rankin scale	N/R	N/R N/R N/R N/R N/R N/R N/R N/R N/R N/R N/R N/R N/R	N/R (sig) N/R (sig) N/R (sig) N/R (sig) N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig) N/R (not sig)

* ADL= Activities of Daily Living, KF-NAP= Kessler Foundation Neglect Assessment Process, FIM= Functional Independence Measure, MMSE= Mini Mental State Exam

† OR= Odds Ratio, HR= Hazard Ratio, IRR= Incidence Rate Ratio

‡ N/R= Not reported, (sig)= Reported as statistically significant at 95% confidence level but no values reported, (not sig)= Reported as not statistically significant at 95% confidence level but no values reported

§ Included in separate multivariate analysis due to collinearity, controlled for other variables

|| Scores derived from OR, not actual OR

Unadjusted hazard ratios presented as adjusted values not reported

** Details of multivariable analysis obtained from author correspondence

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