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# BMJ Open

## A practical and validated fall risk screening instrument for the primary care setting: A systematic review

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5 1 **A practical and validated fall risk screening instrument for the primary care**  
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8 2 **setting: A systematic review**  
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## 16 Abstract

17 **Objective:** Several fall risk screening instruments are available, however it is unclear which instrument is  
18 validated and most suitable for GP practices. This systematic review aims to identify the most suitable fall  
19 risk screening instrument(s) for the primary care setting (i.e. requires limited time, no expensive equipment  
20 and no additional space) with good predictive performance to assess fall risk among independently living  
21 older people.

22 **Design:** A systematic review.

23 **Methods:** An extensive search was conducted in the databases Pubmed, EMBASE CINAHL, Cochran and  
24 PsycINFO. Twenty-seven out of 2492 articles published between January 2000 and July 2020 were included.

25 **Results:** Six fall risk screening instruments were identified; Timed-Up-and-Go test, Gait Speed test, Berg  
26 Balance Scale, Performance Oriented Mobility Assessment, Functional Reach test, Fall History. Most  
27 articles reported AUCs ranging from 0.5-0.7 for these instruments. Sensitivity and specificity varied  
28 substantially across studies (e.g. TUG, sens.: 10-83.3%, spec.: 28.4-96.6%).

29 **Conclusions:** Since the results showed that the predictive performance of none of the included fall risk  
30 screening instruments was sufficient when taking the threshold of Šimundić for good diagnostic accuracy  
31 (AUC>0.7) into account, other ways of screening for high fall risk among independently living older people  
32 in the primary care setting should be investigated. As for now, the most suitable way for assessing fall risk  
33 in the primary care setting appears to be asking about patient's fall history. Compared to the other five  
34 instruments, Fall History requires the least amount of time, no expensive equipment, no training, and no  
35 space (adjustments).

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37  
38 **Key words:** Fall prevention, Screening instrument, Predictive Performance, Primary Care, Review

39

## Strengths and Limitations of this study

- This review is built on extensive literature regarding fall risk screening instruments suitable for the primary care setting and presentation of their predictive performance.
- We endeavoured to reduce bias by only including fall risk screening instruments that have been validated at least three times in different studies and by conducting risk of bias assessment.
- As different studies used different cut-off scores, modified versions of the same tests and presented different outcome measures, it was difficult to combine the results and to make a convincing conclusion.

## 52 Introduction

53 Worldwide, falls are the second leading cause of accidental or unintentional injury deaths [1]. On average,  
54 one in three people aged 65 and older fall at least once a year [2] and yearly an estimated 646,000 people  
55 die due to the consequences of a fall [1]. These numbers are increasing as society is aging [3]. The  
56 consequences of a fall can vary from a scratch or bruise to a hip fracture, brain injury or even death. Falls  
57 can have a huge negative long-lasting impact on the quality of life and self-management of older people  
58 [4-6]. Treatment and rehabilitation of fall incidences correlate with high costs in the health care sector [5,  
59 7]. Therefore, the provision of fall prevention is important for older people.

60 Society is aging and older people live longer independently at home [3]. Their first port of call for health  
61 problems are general practitioners (GPs). The approach between GPs differs, some provide no fall  
62 preventive care at all while others might be very active regarding fall prevention. Only 20% of the older  
63 patients inform their GP about their falls which means that GPs do not know about the occurrence of 80%  
64 of the falls among their patients [8, 9]. Consequently, GPs are often unaware which of their patients are at  
65 risk of falls. This results in delayed or no treatment of fall risk among older people even though potentially  
66 effective fall-preventive interventions are available [10-14].

67 Early identification of high fall risk among older people is a prerequisite to provide adequate care in time  
68 to reduce fall risk. There are numerous screening instruments available to assess fall risk such as the Timed-  
69 Up-and-Go (TUG) test, the Tinetti Balance, the Berg Balance Scale (BBS) and the AGS/BGS/AAOS Guidelines.  
70 However, it is unclear which fall risk screening instruments have good predictive performance.

71 Due to high workload, primary care health providers have limited time. Furthermore, they have limited  
72 resources for expensive equipment (e.g. platforms, sensors) and in general little space in their practice [15,  
73 16]. Therefore, a suitable fall risk screening instrument for GP practices should require limited time, no  
74 expensive equipment and no space adjustments. Hence, this systematic review aims to identify the most  
75 suitable (quick:<5 min, no expensive equipment or specific resources required) fall risk screening  
76 instrument(s) for the primary care setting with good predictive performance to assess fall risk among  
77 independently living older people.

## 78 **Methods**

### 79 **Study selection**

80 A systematic literature search was conducted in the databases Pubmed, EMBASE, Cinahl, Cochrane and  
81 PsycINFO using the search keywords presented in Figure 1 (see Supplementary File 1). Mesh terms were  
82 used when possible. Additional articles were included after snowballing. Figure 2 shows the flowchart of  
83 the literature search.

84 **Figure 1.** Search keywords

85

86 **Figure 2.** Flowchart literature search

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### 88 **Eligibility criteria and study selection**

89 Articles, published between January 2000 and July 2020, were eligible when they met the in- and exclusion  
90 criteria presented in Figure 3. This review only included prospective studies to be able to summarize the  
91 predictive performances of fall risk screening instruments [17]. Additionally, only the screening instruments  
92 that have been assessed in at least three different studies were included in the final analysis to ensure  
93 validity of the included instrument as studies may differ, for example in selected population in age, sex, or  
94 frailty.

95 The first exclusion based on title was performed by WM. All articles from the second exclusion based on  
96 abstract were reviewed by WM. Additionally, JK, CL and IG each reviewed 67 articles of a sample of 200  
97 articles from the second exclusion. As there was high agreement between the reviewers only the sample  
98 of 200 articles was reviewed independently by two reviewers to check if there were differences in scoring.  
99 For the third exclusion, WM reviewed all full texts and JK or CL or IG reviewed each one third of all full  
100 texts. Differences between reviewers were discussed until consensus was reached. In total, 26 articles were  
101 included in this study.



## 102 Quality appraisal

103 Quality of the included studies was assessed independently by two reviewers (WM together with JK, CL or  
104 IG) by using the Quality in Prognosis Study (QUIPS) tool [18, 19]. Articles are classified as having low quality  
105 (\*) referring to high potential bias, moderate quality (\*\*) referring to moderate potential bias or high  
106 quality (\*\*\*) referring to low potential bias. The reviewers resolved differences by discussion until  
107 consensus was reached.

108 **Figure 3.** Eligibility criteria

109

## 110 Analysis

111 This review investigates the predictive performance of prognostic tests that predict the likelihood of  
112 developing a fall. The predictive performance of a prognostic test is often described similarly as for  
113 diagnostic tests, by examining diagnostic accuracy [17]. Diagnostic accuracy refers in this review to being  
114 able to discriminate between fallers and non-fallers correctly by using measures such as sensitivity,  
115 specificity and Area Under the Curve (AUC) [20]. Therefore, data regarding sensitivity, specificity and AUC  
116 were extracted from the articles and described.

117 Sensitivity refers to classifying the individual correctly of being at risk of falls, while specificity refers to  
118 classifying the individual correctly of not being at risk of falls [21]. A diagnostic test has good predictive  
119 value if sensitivity and specificity are >70% [22]. The AUC is the area under the receiver operating  
120 characteristic (ROC) curve which represents the accuracy of the test. With help of the ROC curve, the best  
121 cut-off score for the most optimal sensitivity and specificity can be chosen. The larger the AUC, the better  
122 the test. The accuracy of a diagnostic test is good or excellent if the AUC is >0.7 [20]. We ranked the  
123 outcomes, taken the cut-off values for good sensitivity, specificity and AUC into consideration, to be able  
124 to value the outcomes [20, 22].

125 Furthermore, when analysing the results, also criteria regarding suitability of the fall risk screening  
126 instrument for the primary care setting were taken into account. Primary health care providers have  
127 limited time due to a high workload. Also, they have limited resources for expensive equipment (e.g.  
128 platforms, sensors) and in general little space in their practice [15, 16]. Therefore, when analysing the

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3 129 results, the following criteria for a suitable instrument were taking into account; limited time, no expensive  
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5 130 equipment and no space adjustments.  
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## 11 132 **Patient and public involvement**

13 133 Before conducting the systematic review, an informal focus group was conducted with primary care  
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15 134 professionals, the end-users, to identify their needs and wishes regarding a fall risk screening instrument.  
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17 135 In this study, their needs and wishes were taken into account when analysing the results regarding  
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19 136 suitability of the fall risk screening instruments for the primary care setting.  
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21 137 Patients were not directly involved in this systematic review.  
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## 27 139 **Results**

30 140 The 27 included articles identified six fall risk screening instruments. All instruments are described below  
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32 141 and presented in Table 1. More details about the included articles are provided in Supplementary File 2.  
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### 35 142 *Timed Get up and Go test*

37 143 The Timed Get Up and Go (TUG) test takes only a few minutes to complete and was described in 13 studies  
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39 144 [23-36]. Participants are asked to stand up from a chair, walk 3 meters, turn, walk 3 meters back and to sit  
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41 145 down again. The time measured to conduct this task indicates high or low fall risk. The reported cut-off  
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43 146 scores varied from 10.9 to 13 seconds. Eleven studies described the AUC which varied from 0.46 to 0.89.  
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45 147 Sensitivity varied from 10% to 83.3% and specificity varied from 28.4% to 96.6% in eight studies.  
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### 48 148 *Gait Speed test*

51 149 The Gait Speed test, on a distance of 4m, takes only a few minutes to complete and was evaluated in four  
52  
53 150 studies [27, 37-39]. Participants are asked to walk 4m at usual pace. The time to complete the task is  
54  
55 151 recorded and gait speed is calculated (m/s). The studies of Bongers et al. [37] and Tsutsumimoto et al. [38]  
56  
57 152 showed AUCs of 0.5 and 0.77, respectively. Kang et al. [27] investigated the AUC for different follow up  
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59 153 periods and for any or recurrent falls, which varied from 0.54 to 0.68. Sensitivity and specificity were  
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3 154 reported in two studies [38, 39] which varied from 38.4% to 100% and 23.9% to 84.7% respectively,  
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5 155 depending on the cut-off scores.  
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8 156 *Berg Balance Scale*  
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10 157 The Berg Balance Scale (BBS) evaluates the participants balance based on 14 items with a 5 point-Likert  
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12 158 scale and takes 15-20 minutes to complete. The score for each item varies from 0-4 points with an overall  
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14 159 maximum score of 56 points. Balance is evaluated by asking the participant to perform different sitting,  
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16 160 transferring and standing positions. The study of Muir et al. [40] evaluated what cut-off scores of the BBS  
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19 161 predicted the risk of falling the best by making a difference between a single and multiple falls. They found  
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162 **Table 1.** Included fall risk screening instruments

Instrument	Authors and year	Suitability	N	Cut-off score	AUC (95%CI)	Sens	Spec	Quality	
TUG test	Kojima et al., 2015 [28]	Time: <5min.	259	12.6 s	0.58	0.305	0.895	**	
	Chow et al., 2019 [36]		192	12 s	0.54				
	Alexandre et al., 2012 [23]	Space: ±4 m.	60	12.47 s	0.68 (0.54-0.83)	0.737	0.658	**	
	Wrisley et al., 2010 [35]		35	12.34 s	0.89				
	Pai et al., 2010 [32]	Tools: Stopwatch, chair, tape- measure	13		0.46	0.50 (0.09-0.9)	0.56 (0.40-0.96)	**	
	Bongue et al., 2011 [24]		1759	10.9 s	0.54 (0.52-0.57)				
	Lin et al., 2004 [29]	Training required: Yes	1200		0.61			**	
	Russel et al., 2008 [33]		344		0.63 (0.57-0.69)			**	
	Hofheinz et al., 2016 [25]		120		0.58			**	
	Melzer et al., 2010 [30]		98		0.57			***	
	Trueblood et al., 2001 [34]		180				0.1	0.95	**
	Ollsen Möller et al., 2012 [31]		153	≥12-13 s at 6 months follow up			0.67	0.50	*
				≥12-13 s at 12 months follow up			0.78	0.37	
	Kang et al., 2017 [27]	619	>10.2 s		0.603 (0.545-0.661)			**	
	Kang et al. 2018 [26]				any falls	0.607 (0.549-0.665)			**
any falls					0.642 (0.584-0.700)				
recurrent falls					0.688 (0.602-0.773)				
recurrent falls, cut-off 10.15 s					0.733 (0.645-0.821)	0.675	0.563		
Gait speed (4m)	Tsutsumimoto et al., 2013 [38]	Time: <5 min.	59	0.67m/s	0.77 (0.62-0.92)	0.82	0.71	**	
	Bongers et al., 2015 [37]		352		0.5				

	Vergheze et al., 2002 [39]	Space: ± 5 m.	59	≥12 s		1	0.239	***
				≥14 s		0.769	0.565	
				≥18 s		0.384	0.847	
	Kang et al., 2017 [27]	Tools: Stopwatch, tape- measure	541	any falls	0.563 (0.504-0.622)			**
				any falls	0.586 (0.526-0.647)			
		Training required: Yes		recurrent falls	0.542 (0.445-0.639)			
				recurrent falls	0.680 (0.593-0.768)			
Berg Balance Scale (BBS)	Muir et al., 2008 [40]	Time: 15-20 min.	187	≤53 (for multiple falls)	0.68	0.69 (0.50-0.88)	0.57 (0.47-0.66)	**
		Space: ± 1-2 m.		≤54 (for any fall)	0.59	0.61 (0.50-0.72)	0.53 (0.43-0.63)	
		Tools: Stopwatch, 2 chairs, tape- measure, step bench		≤45 (for multiple falls)		0.42 (0.26-0.61)	0.87 (0.79-0.92)	
				≤45 (for any falls)		0.25 (0.16-0.33)	0.87 (0.79-0.92)	
	Melzer et al., 2010 [30]		98	≤52	0.47			***
	Ersoy et al., 2009 [41]	Training required: Yes	125	≤48		0.686	0.756	*
POMA- Balance	Faber et al., 2006 [43]	Time: ± 10 min.	72	10		0.640 (0.445-0.798)	0.661 (0.530-0.771)	**
	Trueblood et al., 2001 [34]	Space:	180	10		0.24	0.91	**

	Bizovska et al., 2018 [42]	± 1-2 m.	131	NR, multiple fallers vs non-fallers				**
	Vergheze et al., 2002 [39]	Tools: chair without handrails Training required: Yes	59	≤8	0.659	0.89	0,47	
				≤9		0.076	0.913	
				≤10		0.23	0.804	***
POMA-Gait	Trueblood et al., 2001 [34]	Time: ±10 min.	180	9		0.21	0.95	**
	Faber et al., 2006 [43]	Space: ± 1-2 m.	72	9		0.64 (0.445-0.998)	0.625 (0.494-0.74)	**
	Bizovska et al., 2018 [42]	Tools: obstacle-free corridor or space  Training required: Yes	131		NR because NS			**
Functional Reach (FR)	Lin et al., 2004 [29]	Time: <5 min.	1200		0.509			**
	Russel et al., 2008 [33]		344		0.60 (0.54-0.66)			**
	Murphy et al., 2003 [44]	Space: ± 1-2 m.  Tools: Tape-measure  Training	50	8in.		0.73	0.88	*

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		required: Yes						
Fall history	Tiedemann et al., 2010 [49]	Time: <2 min.	362	≥1 fal in the previous year	0.71	0.69 (0.57-0.78)	0.63 (0.57-0.69)	**
	Nitz et al., 2013 [48]		449	History of multiple falls, n.f.s.	0.64			**
	Gerdhem et al., 2005 [46]	Space: N.a.	984	1 fall In the previous year		0.39	0.82	**
				≥2 falls in the previous year compared to ≤ 1 fall		0.46	0.8	
	Coll-Planes et al., 2006 [45]	Tools: None	192	≥1 fall in the previous year		0.595	0.645	**
Lindemann et al., 2008 [47]	Training required: No	65	≥1 fall in the previous year		0.63	0.77	**	

163 Quality assessed with QUIPS tool: \* High bias, \*\* Moderate Bias, \*\*\* Low Bias

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3 168 an AUC of 0.68 for multiple falls with a cut-off score  $\leq 53$  and an AUC of 0.59 for a single fall with a cut-off  
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5 169 score  $\leq 54$ . Melzer et al. [30] found a lower AUC of 0.47. Muir et al. [40] and Ersoy et al. [41] also reported  
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7 170 sensitivity and specificity which varied from 25% to 69% and 53% to 87% respectively.  
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### 10 171 *The Tinetti tests*

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12 172 The Tinetti tests are widely used tests to assess fall risk, however there are many variations. One is the  
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14 173 Performance Oriented Mobility Assessment (POMA) - Total. This test consists of two components to assess  
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16 174 balance (POMA-B) and gait (POMA-G) and takes about 20 minutes to complete. For the POMA-B test, which  
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18 175 was assessed in four studies [34, 39, 42, 43], the participant is asked to perform nine different movements  
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20 176 to assess balance. Depending on the cut-off scores, sensitivity and specificity varied from 23% to 89% and  
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22 177 47% to 91.3% respectively. An AUC of 0.66 was reported by Bizovska et al. [42], however the cut-off scores  
23  
24 178 were not specified and the comparison was about multiple fallers, excluding single time fallers. The POMA-  
25  
26 179 G asks the participant to perform six different movements to assess gait. The POMA-G suggests to conduct  
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28 180 the test in a corridor. Only the study of Bizovska et al. [42] specified the space they used for this test, which  
29  
30 181 was a 30 metre well-lit corridor. Faber et al. [43] and Trueblood et al. [34] reported sensitivities and  
31  
32 182 specificities ranging from 21% to 64% and from 63% to 95% respectively. Bizovska et al. [42] did not report  
33  
34 183 any specific results as they did not find any significant differences between the fallers and non-fallers in  
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36 184 relation to the POMA-G.  
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### 41 185 *The Functional Reach test*

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43 186 The Functional Reach (FR) test was validated in three studies [29, 33, 44]. Participants are asked to hold  
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45 187 their arms in front of them in an angle of 90 degrees, stretch forward as far as possible and to go back to  
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47 188 the beginning position. The distance between beginning position and stretched position is measured which  
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49 189 indicates high or low fall risk. This test takes less than 5 minutes to complete. The AUC was reported in two  
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51 190 studies [29, 33] and varied from 0.51 to 0.60. Murphy et al. [44] mentioned a sensitivity and specificity of  
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53 191 73% and 88% respectively.  
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### 192 *Fall History*

193 Five studies explored the accuracy of Fall History [45-49], which takes only a few minutes to assess. In these  
194 five studies, Fall History had different definitions. The most used definition was at least one fall in the  
195 previous year. The AUC was investigated by Tiedemann et al. [49] and Nitz et al. [48] which varied from  
196 0.64 to 0.71. Sensitivity and specificity were explored in four studies and varied from 39% to 69% and from  
197 63% to 82%, respectively.

### 198 *Quality Appraisal*

199 The methodological quality was assessed of all articles and is presented in Table 1. Three articles were  
200 classified as high quality, 21 articles as moderate quality and three articles as low quality.

## 202 **Discussion**

203 The aim of this study was to identify the most suitable fall risk screening instrument(s) for the primary care  
204 setting (i.e. requires limited time, no expensive equipment and no additional space) with good predictive  
205 performance to assess fall risk among independently living older people. This systematic review identified  
206 six fall risk screening instruments for the primary care setting. The vast majority of the included studies  
207 identified the fall risk among older people over a period of 12 months (range 6 month – 9 years). None of  
208 the six fall risk screening instruments appear to be adequate in discriminating between people with and  
209 without a high fall risk, when taking the thresholds of Šimundić [20] for good diagnostic accuracy (AUC>0.7)  
210 into account. These findings did not alter when only taking the moderate and high quality articles into  
211 account. Four studies did report an AUC > 0.7 for the TUG test [26, 35], Gait Speed test [38] and Fall History  
212 [49], indicating good diagnostic accuracy [20]. However, most articles reported AUC's ranging from 0.5 to  
213 0.7, indicating insufficient diagnostic accuracy for all included instruments. Furthermore, sensitivity and  
214 specificity of the same instrument varied substantially across studies, refraining us from making a  
215 convincing conclusion.

216 The results of this review are also acknowledged by others. For example, even though the TUG test is widely  
217 used to assess fall risk, other studies also showed the lack of predictive ability of the TUG test regarding

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3 218 falls [50, 51]. Furthermore, the study of Gates et al. [52] stated “*At present, recommending any screening*  
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5 219 *test for routine clinical use is not possible. Despite the number of studies that have been conducted, no*  
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7 220 *strong evidence exists that any screening test is useful for identifying fallers.*” With the current systematic  
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9 221 review, eleven years after the review of Gates et al. [52], we have to conclude the same. Conclusive  
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11 222 evidence to identify a fall risk screening instrument with adequate predictive performance and accuracy is  
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14 223 still lacking.

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17 224 Since choice based on predictive performance ability is not possible, suitability for the primary care setting  
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19 225 prevails as for now. Primary health care providers have limited time and lack resources for expensive  
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21 226 equipment, room or training [15, 16]. Considering this, the most suitable instrument identified in this  
22  
23 227 review appears to be patient’s Fall History as it takes only a few minutes to conduct and requires no  
24  
25 228 training, expensive equipment or space (adjustments). The BBS and the Tinetti test would not be suitable  
26  
27 229 as they take 15-20 minutes to complete and require training to conduct. The TUG and Gait Speed tests  
28  
29 230 both are quick (< 5min.), but they require training and space to conduct (>4 metre). The FR test is quick (<  
30  
31 231 5min.) and does not require much space, however it requires more training compared to Fall History and  
32  
33 232 the reported AUCs are also lower compared to Fall History.

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35  
36 233 Even though the diagnostic accuracy of Fall History is insufficient, it is the same or even better than that of  
37  
38 234 most of the other five fall risk screening instruments, see Table 1. Barker et al. [53] also found that Fall  
39  
40 235 History appears to be a suitable screening instrument when exploring the clinometric evaluation of four  
41  
42 236 fall risk assessment tools. They stated that “*the predictive validity of all tools was found to be low, with no*  
43  
44 237 *tool offering greater ability to identify residents who would fall than a simple screening question ‘has the*  
45  
46 238 *resident fallen in the past 12 months?’*. In addition, Fall History is used in many multifactorial assessment  
47  
48 239 tools and algorithms and appears to be an important risk factor for fall risk (OR: NS-14.02) [41, 46, 48, 54-  
49  
50 240 61]. Nevertheless, by using only patient’s Fall History as a screening instrument, first time fallers will not  
51  
52 241 be discovered. This certainly is a huge disadvantage. However, older people might be less willing to start  
53  
54 242 and complete fall prevention interventions when they did not experience a previous fall. They often do not  
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56 243 associate themselves with having a high fall risk. Hence, the experience of a previous fall might influence  
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58 244 motivation to start and complete a fall prevention intervention.

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3 245 According to the study of Nordin et al. [62], screening for fall risk with clinical judgement as well as Fall  
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5 246 History among their population of frail older people was superior to performance-based measures. Meyer  
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7 247 et al. [63] even stated that fall risk screening instruments should be avoided *“since it has no clinical*  
8  
9 248 *consequences other than the waste of scarce nursing resources”*. Due to the increasing work pressure and  
10  
11 249 lack of awareness, health care professionals might not assess a patient’s fall risk when it is based on clinical  
12  
13 250 judgement alone as it is not part of a systematic screening strategy. Systematically screening for fall risk by  
14  
15 251 using patient’s Fall History together with the health care professional’s expertise might therefore be an  
16  
17 252 adequate screening strategy.

### 21 253 **Practice recommendations**

22  
23 254 In daily practice, GPs can ask their older patients during a consultation if they had a fall during the past 12  
24  
25 255 months. Even if the patient says ‘no’, the GP might still notice a high fall risk, e.g. due to walking or sitting  
26  
27 256 difficulties etc. If the GP suspects high fall risk after this brief screening, (s)he can investigate the underlying  
28  
29 257 cause of the fall risk by conducting a multifactorial assessment so adequate care can be offered. Depending  
30  
31 258 on the organization of the GP practice, the GP could also refer the patient to another health care provider,  
32  
33 259 such as the practice nurse specialized in elderly care, who might have more time to investigate the  
34  
35 260 underlying cause of the fall risk. By conducting a brief fall risk screening that leads to a comprehensive  
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37 261 multifactorial assessment, followed up with multifactorial interventions that tackle the identified risk  
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39 262 factors, a patient’s fall rate can be reduced [64-66].

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### 46 264 **Strengths and Limitations**

47  
48 265 The results from this review were difficult to combine. Different studies used different cut-off scores,  
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50 266 modified versions of the same tests and presented different outcome measures. These differences  
51  
52 267 between studies made it difficult to give a convincing conclusion of the results.  
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54 268 Since we have included at least three studies for each instrument, conducting a meta-analysis for each  
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56 269 instrument seems feasible. However, we did not conduct a meta-analysis for two reasons. First, the  
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58 270 diversity between studies that assessed the same instrument was large, e.g. differences in cut-off scores,  
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3 271 follow-up periods, study population (sex, age, in/exclusion criteria) and quality differences. This made a  
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5 272 meta-analysis unsuitable for most instruments. Second, the results from our study are already clear  
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7 273 without conducting a meta-analysis, namely none of the six identified instruments appear to be adequate  
8  
9 274 in discriminating between people with and without a high fall risk, when taking the thresholds of Šimundić  
10  
11 275 [20] for good diagnostic accuracy (AUC>0.7) into account. Another limitation is the possibility of publication  
12  
13 276 bias of studies with worse outcomes, which might have led to an overestimation of the predictive  
14  
15 277 performance of the included screening instruments. Nevertheless, these limitations support our conclusion  
16  
17 278 that none of the included instruments has sufficient predictive performance.  
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### 21 279 **Further Research**

22  
23 280 The underlying cause of falls is complex. This makes it difficult, if not impossible to adequately identify  
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25 281 people with high fall risk with only a physical test or a short questionnaire. None of the fall risk screening  
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27 282 instruments identified in this review are able to identify older people with high fall risk adequately.  
28  
29 283 Therefore, other ways of screening for high fall risk among independently living older people in the primary  
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31 284 care setting should be studied. To improve predictive performance of a fall risk screening instrument, it  
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33 285 might help to develop an instrument that takes a person's behaviour and environment into account.  
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40 287 Overall, the results from this systematic review show that the predictive performance of the six identified  
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42 288 fall risk screening instruments is insufficient. Overall, patient's Fall History appears to be the same or even  
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44 289 better than the other five fall risk screening instruments. In addition, this instrument is most suitable for  
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46 290 the primary care setting as it is quick and does not require equipment, space or training. Patients' Fall  
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48 291 History together with a health care professional's clinical judgement, might be a promising strategy for the  
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50 292 primary care setting to identify older people with high fall risk. When older people with a high fall risk are  
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52 293 identified, they can be offered adequate fall preventive care. This could reduce falls and fear of falling,  
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54 294 which might lead to maintained or improved quality of life and prolonged autonomy of older people.  
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### 57 295 **List of abbreviations**

58 296 GP: General Practitioner  
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3 297 QUIPS: Quality in Prognosis Study  
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5 298 AUC: Area Under the Curve  
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7 299 ROC: Receiver Operating Characteristic  
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9 300 TUG: Timed-Up-and-Go  
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11 301 BBS: Berg Balance Scale  
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13 302 POMA-B: Performance Oriented Mobility Assessment-Balance  
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15 303 POMA-G: Performance Oriented Mobility Assessment-Gait  
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17 304 FR: Functional Reach  
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25 307 **Declarations**

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28 308 **Ethics approval and consent to participate**

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30 309 Ethics approval is not required for this literature review.  
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36 311 **Consent for publication**

37  
38 312 Not applicable.  
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41 313 **Availability of data and materials**

42  
43 314 The datasets used and/or analysed during the current study are available from the corresponding author  
44  
45 315 on reasonable request.  
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51 317 **Competing interests**

52  
53 318 The authors have no conflicts of interests to declare.  
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9 323 study, data collection, analysis, interpretation, or in the writing of this manuscript.  
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15 325 **Author Contributions**  
16

17 326 WM conducted the systematic review and wrote the manuscript. JK, CL and IG reviewed articles for

18  
19 327 inclusion, reviewed the quality check, and provided feedback on the manuscript. All authors read and

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21 328 approved the final manuscript.  
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30 331 Not applicable.  
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3 508 **Figure Legends**  
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7 510 **Figure 1.** Search keywords  
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11 512 **Figure 2.** Flowchart literature search  
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15 514 **Figure 3.** Eligibility criteria  
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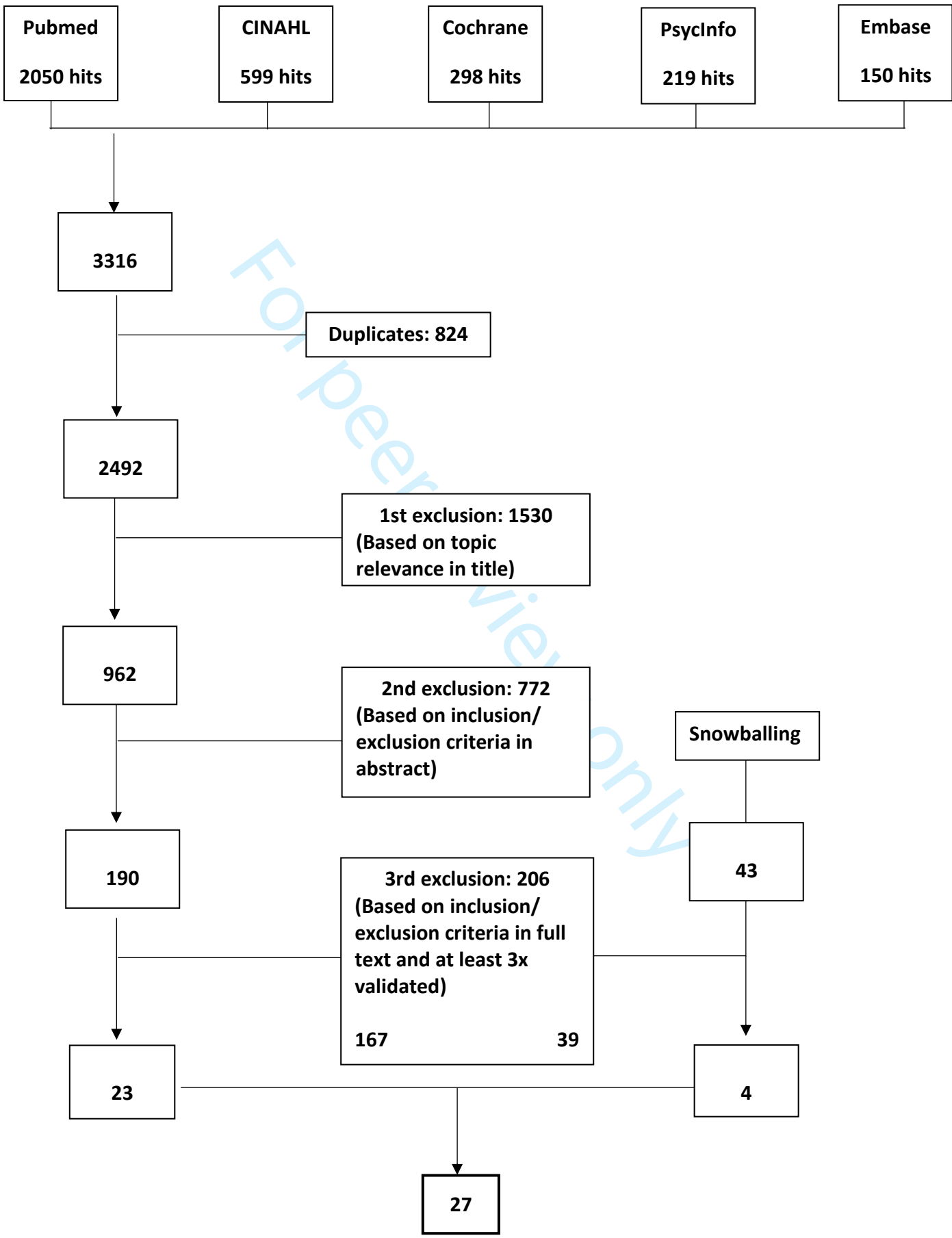
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1 **Figure 1.** Search keywords

2 (Frail Elderly[Mesh] OR Aged[Mesh] OR Frail Elderly\* OR Aged\*)  
3 AND  
4 (Accidental Falls[Mesh] OR Accidental Falls\* OR Falls\*)  
5 AND  
6 (Risk Assessment[Mesh] OR Prognosis[Mesh] OR Diagnosis[Mesh] OR Risk  
7 Assessment\* OR Prognosis\* OR Diagnosis\* OR Screening\* OR Prediction\*)  
8 AND  
9 (Specificity and Sensitivity[Mesh] OR Data Accuracy[Mesh] OR Sensitivity\*  
10 OR Specificity\* OR Accuracy\* OR Validity\*)  
11

Figure 1. Flowchart Literature Review



**Figure 3.** Eligibility criteria

Articles were included when they met the following inclusion criteria:

1. Prospective studies in which the primary or secondary purpose was to evaluate the performance of one or more fall risk instruments for predicting fallers.
2. The participants were older people living in the community or substantially independently
3. Full articles published in English, Dutch or German

Articles were excluded when they met one or more of the following exclusion criteria:

1. Fall risk screening instruments which require expensive computer software programs, other advanced expensive software or instruments not available in usual primary care units (e.g. sensors, electronical platforms, force plates).
2. Literature reviews and studies with no follow up of fall incidents.
3. No reported Area Under the Curve (AUC), sensitivity or specificity of the fall risk screening instruments.
4. Screening instruments specifically developed for or only tested on populations with a specific disease (e.g. cancer, diabetes, Parkinson etc.)
5. The participants were living in hospital or other institutionalised settings

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### Additional file 1

#### Recent queries in pubmed

Search,Query,Items found,Time

#1,"Search (((("Aged"[Mesh]) OR "Frail Elderly"[Mesh] OR Aged\* OR Frail Elderly\* OR Elderly\*)) AND ("Accidental Falls"[Mesh] OR Accidental Falls\* OR Falls\*)) AND (((Risk Assessment"[Mesh]) OR "Diagnosis"[Mesh]) OR "Prognosis"[Mesh] OR Risk Assessment\* OR Diagnos\* OR Prognos\* OR Screen\* OR Predict\*)) AND (((Sensitivity and Specificity"[Mesh]) OR "Reproducibility of Results"[Mesh]) OR "Data Accuracy"[Mesh] OR Sensitivity\* OR Specificity\* OR Accuracy\* OR Reliab\* OR Valid\*) Filters: Full text

Publication date from 2000/01/01 to 2020/07/01

Field: Title/Abstract,1956,03:40:44

## Additional file 2.

### Overview characteristics included articles

Author	N	Age	Gender	Exclusion	Inclusion	Follow up in months	Included instrument
Alexandre et al., 2012 [23]	60	≥60 (60-82)	29 men/ 31 women	PD, history of transitory ischemic attack, stroke, cognitive impairment, wheelchair, fall in the previous 6 months	n.a.	12 months	TUG test
Bizovska et al., 2018 [42]	131	≥60 (mean 70.8, SD 6.7)	23 men/ 108 women	Any injury or surgery on the musculoskeletal system during the last two years before the baseline measurement	Aged ≥60; ii) no known neurological or musculoskeletal problem that may affect gait or balance abilities; iii) ability to stand and walk without any assistance and assisting device	12 months	POMA-B POMA-G
Bongers et al., 2015 [37]	352	≥70 (mean 76.2 (SD 4.3)	all women	too ill to be screened by GP, currently receiving treatment from geriatrician or received comprehensive geriatric assessment in past 3 months	n.a.	12 months	Gait speed
Bongue et al., 2011 [24]	1759	≥65 (65-95, 70.7 (SD 4.6))	862 men/ 897 women	neurological disease, cognitive impairment, unable to understand French or follow simple commands	n.a.	12 months	TUG test
Chow et al., 2019 [36]	192	≥65 (average: 74.4)	81 men/ 111 women	n.a.	aged ≥65, being discharged from the ED, English speaking, had capacity to give consent, and personally identified a risk factor for falling (if a patient reported that they had either fallen in the last year, worried about falling, or admitted that they felt unsteady when standing or walking)	6 months	TUG test
Coll-Planas et al., 2006 [45]	192 (268 with 76 drop-outs)	≥65 (89 >83 years, 103 ≤83 years)	34 men/ 158 women	living in nursing home	Community dwelling elderly aged ≥65	12 months	Fall History
Ersoy et al., 2009 [41]	125	≥50 (50-79, 61.4 (SD 7.9)	all women	unable to walk without assistance or aids	postmenopausal community dwelling women aged 50+	6 months	BBS



Faber et al., 2006 [43]	72 (total 245)	84.9 (SD 6.0) (of total 245)	14 men/ 58 women	in ability to walk 6m with(out) aids, capacity to understand instructions, medical contraindications to participate, cognitive impairment	n.a.	10 months	POMA-B POMA-G
Gerdhem et al., 2005 [46]	984	75 (75.01-75.99)	all women	n.a.	community dwelling women aged 75 in Malmö	12 months	Fall History
Hofheinz et al., 2016 [25]	120	≥60 (60-87, 72.2 (SD 6.8))	26 men/ 94 women	cognitive limitations, neurological or musculoskeletal diagnose	able to walk 10m with(out) aid, able to understand instructions, able to carry glass in one hand	12 months	TUG test
Kang et al., 2017 [27]	541	≥60 (67.4 (SD 5.6))	234 men/ 307 women	Inability to perform the basic activities of daily living and thus could not complete performance-based assessments; visual impairments; current use of drugs (psychotropic drugs, cardiovascular drugs, hypoglycemic agents, non-steroidal anti-inflammatory drugs, analgesics, dopaminergic drugs, PD's drugs or more than four kinds of complex drugs).	Aged ≥60 years and joined the China's national free physical examination programs	12 months	TUG test Gait Speed
Kang et al., 2018 [26]	619	≥60 (60-86, 67.4 (SD 5.6))	262 men/ 357 women	Severe functional impairment, current use of sedative drugs, antiepileptic drugs and so on, refusal to participate in the follow-up of this study	Aged ≥60, who joined the free physical examination program	12 months	TUG test
Kojima et al., 2015 [28]	259	≥65 (72.6 (SD 5.9))	95 men/ 164 women	≥3 falls in past year, unstable medical conditions, already exercising 150min/week	aged ≥65 able to walk independently and participate in group exercise	6 months (24 weeks)	TUG test
Lin et al., 2004 [29]	1200	≥65 (73.4 (SD=NR))	709 men/ 491 women	NR	NR	12 months	TUG test FR test
Lindeman et al., 2008 [47]	65	≥65 (67.7 (SD 6.0))	33 men/ 32 women	use of walking aid, self-reported neurological disorders, or spinal or lower extremity joint pain interacting with stepping performance, inability to come to the research department without help, cognitive impairment	community dwelling elderly aged ≥65	12 months	Fall History

1 2 3 4 5 6 7 8 9 10 11 12 13 14	Melzer et al., 2010 [30]	98	≥65 (65-91, 78.4 (SD 5.7))	26 men/ 72 women	serious visual impairment; inability to ambulate independently; cognitive impairment; severe focal muscle weakness or paralysis; severe peripheral or compression/entrapment neuropathies; symptomatic orthostatic hypotension, respiratory, cardiovascular, musculoskeletal or neurological disorders that might have interfered with participation in the exercise program; cancer, metastatic or under active treatment; and use of medication known to impair balance or strength.	n.a.	12 months	TUG test BBS
15 16 17 18	Muir et al., 2008 [40]	187	≥47 (47-90, 79.4 (SD 5.83))	122 men/ 65 women	n.a.	community dwelling veterans of WWII and the Korean War residing in 3 regions of southwestern Ontario	12 months	BBS
19 20 21	Murphy et al., 2003 [44]	50	≥60 (72.3 (SD 8.6))	13 men/ 37 women	no exclusion based on disease	community dwelling elderly aged ≥60	14 months	FR test
22 23 24 25 26	Nitz et al., 2013 [48]	449	≥40 (40-80, 59.3 (SD 10.6))	all women	n.a.	independently mobile and cognitively competent women from the electoral rool in North Brisbane Health district	108 months (9 year)	Fall History
27 28 29 30 31 32 33 34 35 36 37 38 39	Ollsen Möller et al., 2012 [31]	153	≥65 (66-94, 81.5 (SD 6.3))	51 men/ 102 women	n.a.	Age ≥65, living in the municipality where the study was conducted; needing help with at least two activities of daily living (ADL); admitted to hospital at least twice or with at least four contracts with outpatient or primary healthcare during the previous 12 months; being able to communicate verbally and have not cognitive impairments (i.e. ≥25 MMSE)	12 months	TUG test

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Pai et al., 2010 [32]	13	≥65 (65-85, 72 (SD 5))	9 men/ 4 women	musculoskeletal, neurological, cognitive or other systemic disorders, osteopenic or osteoprotic, cognitive impairment, symptomatic postural hypotension	ambulatory community dwelling elderly	9-32 months	TUG test
Russell et al., 2008 [33]	344	≥60 (75.9 (SD 8.5))	106 men/ 238 women	n.a.	community dwelling elderly aged ≥60 presented to an ED as a result of a fall being directly discharged home following emergency care and able to walk independently	12 months	TUG test FR test
Tiedemann et al., 2010 [49]	362	≥74 (74-98, 80.25 (SD=4.5))	128 men/ 234 women	blindness, minimal English language skills, and cognitive impairment	community dwelling elderly aged 63-95 resided in Sydney, Australia	12 months	Fall History
Trueblood et al., 2001 [34]	180	≥60 (60-96, 77.9 (SD 7.26))	37 men/ 143 women	cognitive deficits, underlying neurological problems	aged ≥60, able to stand for 5 min. without aid, able to walk 40 feet at one time without aid.	19 months	TUG test POMA-B POMA-G
Tsutsumimoto et al., 2013 [38]	59	≥65 (Non-fallers 84.0 (SD 1.1) 85.5 (SD 1.4))	11 men/ 48 women	very severe cardiac, pulmonary, musculoskeletal, or neuropathological disorders associated with inability to step safely, cognitive impairment	community-dwelling older people receiving long-term care services aged ≥65, able to walk independently, and having adequate hearing and vision	12 months	Gait Speed
Verghese et al., 2002 [39]	59	≥65 (Nonfallers 79.7 (SD 6.6) Fallers 79.4 (SD 5.7))	25 men/ 34 women	severe visual loss interfering with completion of neuropsychological tests, non-English or non-Spanish speaking, institutionalization, healthy enough to make a clinic visit	community dwelling elderly aged ≥65	12 months	Gait Speed POMA-B

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Wrisley et al., 2010 [35]	35	60-90 (72..9 (SD 7.8))	17 men/ 18 women	cognitive impairment, history of osteoporosis, recent fractures, or lower-extremity surgery; history of progressive neuromuscular disorder; history of whiplash, neck injury, or current complaints of neck pain; history of unstable agina or uncontrolled cardiorespiratory problems; taking any medications that might affect balance; history of any fall in past 6 months and more than one fall in the last year; pain in any segment greater than 2/10 on a 10-point verbal analog scale; not returning the monthly fall calendar	community dwelling elderly aged 60-90 able to stand independently longer than 1 min.	months	TUG test
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# PRISMA 2009 Checklist

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Section/topic	#	Checklist item	Reported on page #
<b>TITLE</b>			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	Title, page 1
<b>ABSTRACT</b>			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	Abstract, page 2
<b>INTRODUCTION</b>			
Rationale	3	Describe the rationale for the review in the context of what is already known.	Background, page 3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	PICO: Background, page 3 S: Methods, Analysis/Figure 3
<b>METHODS</b>			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	N/A
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g. years considered, language, publication status) used as criteria for eligibility, giving rationale.	Methods, Figure 3
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	Methods, Study selection
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Methods, Figure 1
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	Methods, Eligibility criteria and study selection
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	Methods, Eligibility



# PRISMA 2009 Checklist

			criteria and study selection
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	Methods, Analysis
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	Methods, Quality appraisal
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	N/A
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I <sup>2</sup> ) for each meta-analysis.	N/A

Page 1 of 2

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	N/A
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
<b>RESULTS</b>			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Methods, Figure 2
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Additional File 2
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Results, Table 1
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	N/A
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	N/A
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	N/A
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
<b>DISCUSSION</b>			



# PRISMA 2009 Checklist

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Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	Discussion, page 8-10
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	Discussion, Limitations
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	Discussion, page 8-10
<b>FUNDING</b>			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data), role of funders for the systematic review.	Declarations, Funding

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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# BMJ Open

## A practical and validated tool to assess fall risk in the primary care setting: A systematic review

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-045431.R1
Article Type:	Original research
Date Submitted by the Author:	12-Mar-2021
Complete List of Authors:	Meekes, Wytske; Tilburg University Tranzo Scientific Centre for Care and Welfare, Korevaar, J; Netherlands Institute for Health Services Research (NIVEL), Leemrijse, Chantal; NIVEL Van de Goor, Ien ; Tilburg University Tranzo Scientific Centre for Care and Welfare
<b>Primary Subject Heading</b>:	General practice / Family practice
Secondary Subject Heading:	Public health
Keywords:	GENERAL MEDICINE (see Internal Medicine), PRIMARY CARE, PREVENTIVE MEDICINE, PUBLIC HEALTH

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5 1 **A practical and validated tool to assess fall risk in the primary care setting: A**  
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8 2 **systematic review**  
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10 3 Wytse M.A. Meekes<sup>1\*</sup>, Joke C. Korevaar<sup>2</sup>, Chantal J. Leemrijse<sup>2</sup>, Ien A.M. van de Goor<sup>1</sup>

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## 16 Abstract

17 **Objective:** Several fall risk assessment tools are available, however it is unclear which tool is validated and  
18 most suitable for GP practices. This systematic review aims to identify the most suitable fall risk assessment  
19 tool(s) for the primary care setting (i.e. requires limited time, no expensive equipment and no additional  
20 space) with good predictive performance to assess fall risk among independently living older people.

21 **Design:** A systematic review based on prospective studies.

22 **Methods:** An extensive search was conducted in the databases Pubmed, EMBASE, CINAHL, Cochrane and  
23 PsycINFO. Tools were excluded when they require expensive and/or advanced software not available in  
24 usual primary care units and if they were not validated in at least three different studies. Twenty-seven out  
25 of 2492 articles published between January 2000 and July 2020 were included.

26 **Results:** Six fall risk assessment tools were identified; Timed-Up-and-Go test, Gait Speed test, Berg Balance  
27 Scale, Performance Oriented Mobility Assessment, Functional Reach test, Fall History. Most articles  
28 reported AUCs ranging from 0.5-0.7 for these tools. Sensitivity and specificity varied substantially across  
29 studies (e.g. TUG, sens.: 10-83.3%, spec.: 28.4-96.6%).

30 **Conclusions:** Since the results showed that the predictive performance of none of the included fall risk  
31 assessment tools was sufficient (AUC<0.7), other ways of assessing high fall risk among independently living  
32 older people in the primary care setting should be investigated. As for now, the most suitable way for  
33 assessing fall risk in the primary care setting appears to be asking patients about their fall history.  
34 Compared to the other five tools, Fall History requires the least amount of time, no expensive equipment,  
35 no training, and no space (adjustments). Nonetheless, the health care professional's clinical judgement  
36 remains most important as (s)he can still identify a high fall risk based on clinical judgement even though  
37 the patient has no fall history.

38  
39 **Key words:** Fall prevention, Fall risk assessment tools, Predictive Performance, Primary Care, Review

## Strengths and Limitations of this study

- This review is built on extensive literature regarding fall risk assessment tools suitable for the primary care setting and presentation of their predictive performance.
- We endeavoured to reduce bias by only including fall risk assessment tools that have been validated at least three times in different studies and by conducting risk of bias assessment.
- As different studies used different cut-off scores, modified versions of the same tools and presented different outcome measures, it was difficult to combine the results and to make a convincing conclusion.

## 52 Introduction

53 Worldwide, falls are the second leading cause of accidental or unintentional injury deaths [1]. On average,  
54 one in three people aged 65 and older fall at least once a year [2] and yearly an estimated 646,000 people  
55 die due to the consequences of a fall [1]. These numbers are increasing as society is aging [3]. The  
56 consequences of a fall can vary from a scratch or bruise to a hip fracture, brain injury or even death [4, 5].  
57 Falls can have a huge negative long-lasting impact on the quality of life and self-management of older  
58 people [4-6]. Treatment and rehabilitation of fall incidences correlate with high costs in the health care  
59 sector [5, 7]. Therefore, the provision of fall prevention is important for older people.

60 Society is aging and older people live longer independently at home [3]. Their first port of call for health  
61 problems are general practitioners (GPs). The approach between GPs differs, some provide no fall  
62 preventive care at all while others might be very active regarding fall prevention. Only 20% of the older  
63 patients inform their GP about their falls which means that GPs do not know about the occurrence of 80%  
64 of the falls among their patients [8, 9]. Consequently, GPs are often unaware which of their patients are at  
65 risk of falls. This results in delayed or no treatment of fall risk among older people even though potentially  
66 effective fall-preventive interventions are available [10-14].

67 Early identification of high fall risk among older people is a prerequisite to provide adequate care in time  
68 to reduce fall risk. There are numerous tools available to assess fall risk such as the Timed-Up-and-Go (TUG)  
69 test, the Tinetti Balance, the Berg Balance Scale (BBS) and the American Geriatrics Society/British  
70 Geriatrics Society clinical practice guidelines. Gates et al. (2008) summarized in a previous review the  
71 accuracy of screening tools for predicting risk of falling in community-living older adults. Gates et al.  
72 concluded that there was insufficient evidence to show that any screening instrument was adequate for  
73 predicting falls. Also, no implications for practice were provided or taken into account when reporting the  
74 results. Therefore, it is still unclear which fall risk assessment tools have good predictive performance and  
75 might be suitable for practice.

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3 77 Due to high workload, primary care health providers have limited time [15, 16]. Furthermore, they have  
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5 78 limited resources for expensive equipment (e.g. platforms, sensors) and in general little space in their  
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7 79 practice [17-20]. Therefore, a suitable fall risk assessment tools for GP practices should require limited  
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9 80 time, no expensive equipment and no space adjustments. Hence, this systematic review aims to identify  
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11 81 the most suitable (quick:<5 min, no expensive equipment or specific resources required) fall risk  
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14 82 assessment tool(s) for the primary care setting with good predictive performance to assess fall risk among  
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16 83 independently living older people.  
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## 22 85 **Methods**

### 25 86 **Study selection**

27 87 A systematic literature search was conducted in the databases Pubmed, EMBASE, CINAHL, Cochrane and  
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29 88 PsycINFO using the search keywords presented in Figure 1 (see Additional File 1). Mesh terms were used  
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31 89 when possible. Additional articles were included after snowballing. Figure 2 shows the flowchart of the  
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33 90 literature search.  
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37 91 **Figure 1.** Search keywords  
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40 93 **Figure 2.** Flowchart literature search  
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### 45 95 **Eligibility criteria and study selection**

46 96 The proportion of older people is increasing and the current population of older people age differently  
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48 97 compared to 20 years ago (e.g. people get older, more chronic diseases) [21, 22]. Because it is important  
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50 98 that suitable fall risk assessment tools are validated in the current population of older people, articles  
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52 99 published between January 2000 and July 2020 were included when they met the in- and exclusion criteria  
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54 100 presented in Figure 3.  
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57 101 This review only included prospective studies to be able to summarize the predictive performances of fall  
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59 102 risk assessment tools [23]. Additionally, only the tools that have been assessed in at least three different  
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103 studies were included in the final analysis to ensure validity of the included tool as studies may differ, for  
104 example in selected population in age, sex, or frailty.

105 The first exclusion based on title was performed by WM. All articles from the second exclusion based on  
106 abstract were reviewed by WM. Additionally, JK, CL and IG each reviewed 67 articles of a sample of 200  
107 articles from the second exclusion. As there was high agreement between the reviewers only the sample  
108 of 200 articles was reviewed independently by two reviewers to check if there were differences in scoring.  
109 For the third exclusion, WM reviewed all full texts and JK or CL or IG reviewed each one third of all full  
110 texts. Differences between reviewers were discussed until consensus was reached. In total, 26 articles were  
111 included in this study.

### 112 **Quality appraisal**

113 Quality of the included studies was assessed independently by two reviewers (WM together with JK, CL or  
114 IG) by using the Quality in Prognosis Study (QUIPS) tool [24, 25]. Articles are classified as having low quality  
115 (\*) referring to high potential bias, moderate quality (\*\*) referring to moderate potential bias or high  
116 quality (\*\*\*) referring to low potential bias. The reviewers resolved differences by discussion until  
117 consensus was reached.

### 118 **Figure 3. Eligibility criteria**

### 120 **Analysis**

121 This review investigates the predictive performance of prognostic tests that predict the likelihood of  
122 experiencing a fall. The predictive performance of a prognostic test is often described similarly as for  
123 diagnostic tests, by examining diagnostic accuracy [23]. Diagnostic accuracy refers in this review to being  
124 able to discriminate between fallers and non-fallers correctly by using measures such as sensitivity,  
125 specificity and Area Under the Curve (AUC) [26]. Therefore, data regarding sensitivity, specificity and AUC  
126 were extracted from the articles and described.

127 Sensitivity refers to classifying the individual correctly of being at risk of falls, while specificity refers to  
128 classifying the individual correctly of not being at risk of falls [27]. A diagnostic test has good predictive

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3 129 value if sensitivity and specificity are >70% [28]. The AUC is the area under the receiver operating  
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5 130 characteristic (ROC) curve which represents the accuracy of the test. With help of the ROC curve, the best  
6  
7 131 cut-off score for the most optimal sensitivity and specificity can be chosen. The larger the AUC, the better  
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9 132 the test. The accuracy of a diagnostic test is good or excellent if the AUC is >0.7 [26]. We ranked the  
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11 133 outcomes, taking the cut-off values for good sensitivity, specificity and AUC into consideration, to be able  
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14 134 to value the outcomes [26, 28].

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17 135 Furthermore, when analysing the results, criteria regarding suitability of the fall risk assessment tool for  
18  
19 136 the primary care setting were taken into account. Primary health care providers have limited time due to  
20  
21 137 a high workload [15, 16, 19, 20]. Also, they have limited resources for expensive equipment (e.g. platforms,  
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23 138 sensors) and in general little space in their practice [17, 18]. Therefore, when analysing the results, the  
24  
25 139 following criteria for a suitable tool were taken into account; limited time, no expensive equipment and  
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27 140 no space adjustments.

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### 32 33 142 **Patient and public involvement**

34 143 Before conducting the systematic review, an informal focus group was conducted with primary care  
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36 144 professionals (4 GPs, 2 practice nurses and 3 district nurses), the end-users, to identify their needs and  
37  
38 145 wishes regarding a fall risk assessment tool. The results from this informal focus group, together with  
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40 146 previous literature, defined the suitability criteria used in this study. Hence, the needs and wishes of the  
41  
42 147 primary care professionals were taken into account when analysing the results in this review.

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45 148 Patients were not directly involved in this systematic review.

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### 50 51 150 **Results**

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54 151 The 27 included articles identified six fall risk assessment tools. All tools are described below and presented  
55  
56 152 in Table 1. More details about the included articles are provided in Additional File 2.



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3 153 *Timed Get up and Go test*  
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5 154 The Timed Get Up and Go (TUG) test takes only a few minutes to complete and was described in 14 studies  
6  
7 155 [29-42]. Participants are asked to stand up from a chair, walk 3 meters, turn, walk 3 meters back and to sit  
8  
9 156 down again. The time taken to conduct this task indicates high or low fall risk. The reported cut-off scores  
10  
11 157 varied from 10.9 to 13 seconds. Eleven studies described the AUC which varied from 0.46 to 0.89. Sensitivity  
12  
13 158 varied from 10% to 83.3% and specificity varied from 28.4% to 96.6% in eight studies.  
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16  
17 159 *Gait Speed test*  
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19 160 The Gait Speed test, on a distance of 4m, takes only a few minutes to complete and was evaluated in four  
20  
21 161 studies [33, 43-45]. Participants are asked to walk 4m at usual pace. The time to complete the task is  
22  
23 162 recorded and gait speed is calculated (m/s). The studies of Bongers et al. [43] and Tsutsumimoto et al. [44]  
24  
25 163 showed AUCs of 0.5 and 0.77, respectively. Kang et al. [33] investigated the AUC for different follow up  
26  
27 164 periods and for any or recurrent falls, which varied from 0.54 to 0.68. Sensitivity and specificity were  
28  
29 165 reported in two studies [44, 45] which varied from 38.4% to 100% and 23.9% to 84.7% respectively,  
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31 166 depending on the cut-off scores.  
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35 167 *Berg Balance Scale*  
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37 168 The Berg Balance Scale (BBS) evaluates the participants balance based on 14 items with a 5 point-Likert  
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39 169 scale and takes 15-20 minutes to complete. The score for each item varies from 0-4 points with an overall  
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41 170 maximum score of 56 points. Balance is evaluated by asking the participant to perform different sitting,  
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43 171 transferring and standing positions. The study of Muir et al. [46] evaluated what cut-off scores of the BBS  
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45 172 predicted the risk of falling the best by making a difference between a single and multiple falls. They found  
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173 **Table 1.** Included fall risk assessment tools

Tools	Authors and year	Suitability	N	Cut-off score <sup>1</sup>	AUC (95%CI)	Sens	Spec	Quality <sup>2</sup>	
Timed Get Up and Go test	Kojima et al., 2015 [28]	Time: <5min.	259	12.6 s	0.58	0.305	0.895	**	
	Chow et al., 2019 [36]		192	12 s	0.54				
	Alexandre et al., 2012 [23]	Space: ±4 m.	60	12.47 s	0.68 (0.54-0.83)	0.737	0.658	**	
	Wrisley et al., 2010 [35]		35	12.34 s	0.89				
	Pai et al., 2010 [32]	Tools: Stopwatch, chair, tape- measure	13		0.46	0.50 (0.09-0.9)	0.56 (0.40-0.96)	**	
	Bongue et al., 2011 [24]		1759	10.9 s	0.54 (0.52-0.57)				
	Lin et al., 2004 [29]		1200		0.61	Training required: Yes		**	
	Russel et al., 2008 [33]		344		0.63 (0.57-0.69)		**		
	Hofheinz et al., 2016 [25]		120		0.58		**		
	Melzer et al., 2010 [30]		98		0.57		***		
	Trueblood et al., 2001 [34]		180				0.1	0.95	**
	Ollsen Möller et al., 2012 [31]		153	≥12-13 s at 6 months follow up			0.67	0.50	*
			≥12-13 s at 12 months follow up		0.78	0.37			
	Kang et al., 2017 [27]	619	>10.2 s		0.603 (0.545-0.661)			**	
Kang et al. 2018 [26]				any falls	0.607 (0.549-0.665)			**	
				any falls	0.642 (0.584-0.700)				
				recurrent falls	0.688 (0.602-0.773)				
				recurrent falls, cut-off 10.15 s	0.733 (0.645-0.821)				0.675
Gait speed test (4m)	Tsutsumimoto et al., 2013 [38]	Time: <5 min.	59	0.67m/s	0.77 (0.62-0.92)	0.82	0.71	**	
	Bongers et al., 2015 [37]		352		0.5				**

	Vergheze et al., 2002 [39]	Space: ± 5 m.	59	≥12 s		1	0.239	***
				≥14 s		0.769	0.565	
				≥18 s		0.384	0.847	
	Kang et al., 2017 [27]	Tools: Stopwatch, tape- measure	541	any falls	0.563 (0.504-0.622)			**
				any falls	0.586 (0.526-0.647)			
		Training required: Yes		recurrent falls	0.542 (0.445-0.639)			
				recurrent falls	0.680 (0.593-0.768)			
Berg Balance Scale	Muir et al., 2008 [40]	Time: 15-20 min.	187	≤53 (for multiple falls)	0.68	0.69 (0.50-0.88)	0.57 (0.47-0.66)	**
		Space: ± 1-2 m.		≤54 (for any fall)	0.59	0.61 (0.50-0.72)	0.53 (0.43-0.63)	
		Tools: Stopwatch, 2 chairs, tape- measure, step bench		≤45 (for multiple falls)		0.42 (0.26-0.61)	0.87 (0.79-0.92)	
				≤45 (for any falls)		0.25 (0.16-0.33)	0.87 (0.79-0.92)	
	Melzer et al., 2010 [30]		98	≤52	0.47			***
	Ersoy et al., 2009 [41]	Training required: Yes	125	≤48		0.686	0.756	*
Performance Oriented Mobility Assessment -	Faber et al., 2006 [43]	Time: ± 10 min.	72	10		0.640 (0.445-0.798)	0.661 (0.530-0.771)	**
	Trueblood et al., 2001 [34]	Space:	180	10		0.24	0.91	**

Balance	Bizovska et al., 2018 [42]	± 1-2 m.	131	NR, multiple fallers versus non-fallers	0.659	0.89	0,47	**
	Vergheze et al., 2002 [39]	Tools: chair without handrails Training required: Yes	59	≤8		0.076	0.913	***
				≤9		0.23	0.804	
				≤10		0.615	0.695	
Performance Oriented Mobility Assessment - Gait	Trueblood et al., 2001 [34]	Time: ±10 min.	180	9		0.21	0.95	**
	Faber et al., 2006 [43]	Space: ± 1-2 m.	72	9		0.64 (0.445-0.798)	0.625 (0.494-0.74)	**
	Bizovska et al., 2018 [42]	Tools: obstacle-free corridor or space  Training required: Yes	131		NR because NS			**
Functional Reach test	Lin et al., 2004 [29]	Time: <5 min.	1200		0.509			**
	Russel et al., 2008 [33]		344		0.60 (0.54-0.66)			**
	Murphy et al., 2003 [44]	Space: ± 1-2 m.  Tools: Tape-measure  Training	50	8in.		0.73	0.88	*

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		required: Yes							
Fall History	Tiedemann et al., 2010 [49]	Time: <2 min.	362	≥1 fall in the previous year	0.71	0.69 (0.57-0.78)	0.63 (0.57-0.69)	**	
	Nitz et al., 2013 [48]	Space: N.a.	449	History of multiple falls (not further specified)	0.64			**	
	Gerdhem et al., 2005 [46]		984	1 fall in the previous year		0.39	0.82	**	
					≥2 falls in the previous year compared to ≤ 1 fall		0.46	0.8	
	Coll-Planes et al., 2006 [45]	Tools: None	192	≥1 fall in the previous year		0.595	0.645	**	
	Lindemann et al., 2008 [47]	Training required: No	65	≥1 fall in the previous year		0.63	0.77	**	

174 <sup>1</sup> s: seconds / m: meters / in: inch

175 <sup>2</sup>Quality assessed with QUIPS tool: \* High bias, \*\* Moderate Bias, \*\*\* Low Bias

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3 180 an AUC of 0.68 for multiple falls with a cut-off score  $\leq 53$  and an AUC of 0.59 for a single fall with a cut-off  
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5 181 score  $\leq 54$ . Melzer et al. [36] found a lower AUC of 0.47. Muir et al. [46] and Ersoy et al. [47] also reported  
6  
7 182 sensitivity and specificity which varied from 25% to 69% and 53% to 87% respectively.  
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### 10 183 *The Tinetti tests*

11  
12 184 The Tinetti tests are widely used tests to assess fall risk, however there are many variations. One is the  
13  
14 185 Performance Oriented Mobility Assessment (POMA) - Total. This test consists of two components to assess  
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16 186 balance (POMA-B) and gait (POMA-G) and takes about 20 minutes to complete. For the POMA-B test, which  
17  
18 187 was assessed in four studies [40, 45, 48, 49], the participant is asked to perform nine different movements  
19  
20 188 to assess balance. Depending on the cut-off scores, sensitivity and specificity varied from 23% to 89% and  
21  
22 189 47% to 91.3% respectively. An AUC of 0.66 was reported by Bizovska et al. [48], however the cut-off scores  
23  
24 190 were not specified and the comparison was about multiple fallers, excluding single time fallers. The POMA-  
25  
26 191 G asks the participant to perform six different movements to assess gait. The POMA-G suggests to conduct  
27  
28 192 the test in a corridor. Only the study of Bizovska et al. [48] specified the space they used for this test, which  
29  
30 193 was a 30 metre well-lit corridor. Faber et al. [49] and Trueblood et al. [40] reported sensitivities and  
31  
32 194 specificities ranging from 21% to 64% and from 63% to 95% respectively. Bizovska et al. [48] did not report  
33  
34 195 any specific results as they did not find any significant differences between the fallers and non-fallers in  
35  
36 196 relation to the POMA-G.  
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### 41 197 *The Functional Reach test*

42  
43 198 The Functional Reach (FR) test was validated in three studies [35, 39, 50]. Participants are asked to hold  
44  
45 199 their arms in front of them in an angle of 90 degrees, stretch forward as far as possible and to go back to  
46  
47 200 the beginning position. The distance between beginning position and stretched position is measured which  
48  
49 201 indicates high or low fall risk. This test takes less than 5 minutes to complete. The AUC was reported in two  
50  
51 202 studies [35, 39] and varied from 0.51 to 0.60. Murphy et al. [50] mentioned a sensitivity and specificity of  
52  
53 203 73% and 88% respectively.  
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### 204 *Fall History*

205 Five studies explored the accuracy of Fall History (FH) [51-55], which takes only a few minutes to assess. In  
206 these five studies, FH had different definitions. The most used definition was at least one fall in the previous  
207 year. The AUC was investigated by Tiedemann et al. [55] and Nitz et al. [54] which varied from 0.64 to 0.71.  
208 Sensitivity and specificity were explored in four studies and varied from 39% to 69% and from 63% to 82%,  
209 respectively.

### 210 *Quality Appraisal*

211 The methodological quality was assessed of all articles and is presented in Table 1. Three articles were  
212 classified as high quality, 21 articles as moderate quality and three articles as low quality.

213

### 214 **Discussion**

215 The aim of this study was to identify the most suitable fall risk assessment tools (s) for the primary care  
216 setting (i.e. requires limited time, no expensive equipment and no additional space) with good predictive  
217 performance to assess fall risk among independently living older people. This systematic review identified  
218 six fall risk assessment tools for the primary care setting. The vast majority of the included studies identified  
219 the fall risk among older people over a period of 12 months (mean 15 months; range 6 month – 9 years),  
220 see Additional file 2. None of the six fall risk assessment tools appear to be adequate in discriminating  
221 between people with and without a high fall risk, when taking the thresholds of Šimundić [26] for good  
222 diagnostic accuracy (AUC>0.7) into account. These findings did not alter when only taking the moderate  
223 and high quality articles into account. Four studies did report an AUC > 0.7 for the TUG test [32, 41], Gait  
224 Speed test [44] and FH[55], indicating good diagnostic accuracy [26]. However, most articles reported  
225 AUC's ranging from 0.5 to 0.7, indicating insufficient diagnostic accuracy for all included tools. Furthermore,  
226 sensitivity and specificity of the same tool varied substantially across studies, refraining us from making a  
227 convincing conclusion.

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2  
3 228 The results of this review are also acknowledged by others. For example, even though the TUG test is widely  
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5 229 used to assess fall risk, other studies also showed the lack of predictive ability of the TUG test regarding  
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7 230 falls [56, 57]. Furthermore, the study of Gates et al. [58] stated "*At present, recommending any screening*  
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9 231 *test for routine clinical use is not possible. Despite the number of studies that have been conducted, no*  
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11 232 *strong evidence exists that any screening test is useful for identifying fallers.*" With the current systematic  
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14 233 review, thirteen years after the review of Gates et al. [58], we have to conclude the same. Conclusive  
15  
16 234 evidence to identify a fall risk assessment tools with adequate predictive performance and accuracy is still  
17  
18 235 lacking.

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21 236 Since choice based on predictive performance ability is not possible, suitability for the primary care setting  
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23 237 prevails as for now. Primary health care providers have limited time and lack resources for expensive  
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25 238 equipment, room or training [15-20]. Considering this, the most suitable tool identified in this review  
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27 239 appears to be FH as it takes only a few minutes to conduct and requires no training, expensive equipment  
28  
29 240 or space (adjustments). The BBS and the Tinetti test would not be suitable as they take 15-20 minutes to  
30  
31 241 complete and require training to conduct. The TUG and Gait Speed tests both are quick (< 5min.), but they  
32  
33 242 require training and space to conduct (>4 metre). The FR test is quick (< 5min.) and does not require much  
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35 243 space, however it requires more training compared to FH and the reported AUCs are also lower compared  
36  
37 244 to FH.

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40 245 Even though the diagnostic accuracy of FH is insufficient, it is the same or even better than that of most of  
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42 246 the other five fall risk assessment tools, see Table 1. Barker et al. [59] also found that FH appears to be a  
43  
44 247 suitable assessment tool when exploring the clinometric evaluation of four fall risk assessment tools. They  
45  
46 248 stated that "*the predictive validity of all tools was found to be low, with no tool offering greater ability to*  
47  
48 249 *identify residents who would fall than a simple screening question 'has the resident fallen in the past 12*  
49  
50 250 *months?'*". In addition, patient's fall history is used in many multifactorial assessment tools and algorithms  
51  
52 251 and appears to be an important risk factor for fall risk (OR: NS-14.02) [47, 52, 54, 60-67]. Nevertheless, by  
53  
54 252 using only patient's fall history as a fall risk assessment tool, first time fallers will not be discovered. This  
55  
56 253 certainly is a huge disadvantage. However, older people might be less willing to start and complete fall  
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58 254 prevention interventions when they did not experience a previous fall. They often do not associate  
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255 themselves with having a high fall risk [68, 69]. Hence, the experience of a previous fall might influence  
256 motivation to start and complete a fall prevention intervention [70].

257 According to the study of Nordin et al. [71], assessment of fall risk with clinical judgement as well as FH  
258 among their population of frail older people was superior to performance-based measures. Meyer et al.  
259 [72] even stated that fall risk assessment tools should be avoided *"since it has no clinical consequences*  
260 *other than the waste of scarce nursing resources"*. Due to the increasing work pressure [15-18] and lack of  
261 awareness [73, 74], health care professionals might not assess a patient's fall risk when it is based on clinical  
262 judgement alone as it is not part of a systematic assessment strategy. Systematically assessing for fall risk  
263 by using FH together with the health care professional's expertise might therefore be an adequate strategy.

#### 264 **Practice recommendations**

265 In daily practice, GPs can ask their older patients during a consultation if they had a fall during the past 12  
266 months. Even if the patient says 'no', the GP might still notice a high fall risk based on clinical judgement  
267 (e.g. walking or sitting difficulties due to strength and balance problems, dizziness, use of benzodiazepines,  
268 visual impairment, etc.). If the GP suspects high fall risk after this brief assessment, (s)he can investigate  
269 the underlying cause of the fall risk by conducting a multifactorial assessment so adequate care can be  
270 offered. Depending on the organization of the GP practice, the GP could also refer the patient to another  
271 health care provider, such as the practice nurse specialized in elderly care, who might have more time to  
272 investigate the underlying cause of the fall risk. By conducting a brief fall risk assessment that leads to a  
273 comprehensive multifactorial assessment to identify the underlying causes, followed up with multifactorial  
274 interventions that tackle the identified risk factors, a patient's fall rate can be reduced [75-77]. As pointed  
275 out in the American Geriatrics Society/British Geriatrics Society clinical practice guidelines, it is  
276 recommended to conduct a fall risk assessment annually [78].

277

#### 278 **Strengths and Limitations**

279 The results from this review were difficult to combine. Different studies used different cut-off scores,  
280 modified versions of the same tests and presented different outcome measures. These differences

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3 281 between studies made it difficult to give a convincing conclusion of the results.  
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5 282 Since we have included at least three studies for each tool, conducting a meta-analysis for each tool seems  
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7 283 feasible. However, we did not conduct a meta-analysis for two reasons. First, the diversity between studies  
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9 284 that assessed the same tools was large, e.g. differences in cut-off scores, follow-up periods, study  
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11 285 population (sex, age, in/exclusion criteria) and quality differences. This made a meta-analysis unsuitable  
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13  
14 286 for most tools. Second, the results from our study are already clear without conducting a meta-analysis,  
15  
16 287 namely none of the six identified tools appear to be adequate in discriminating between people with and  
17  
18 288 without a high fall risk, when taking the thresholds of Šimundić [26] for good diagnostic accuracy (AUC>0.7)  
19  
20 289 into account. Another limitation is the possibility of publication bias of studies with worse outcomes, which  
21  
22 290 might have led to an overestimation of the predictive performance of the included fall risk assessment  
23  
24 291 tools. Nevertheless, these limitations support our conclusion that none of the included tools has sufficient  
25  
26 292 predictive performance.  
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### 29 293 **Further Research**

30  
31 294 The underlying cause of falls is often multi-factorial and complex. This makes it difficult, if not impossible  
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33 295 to adequately identify people with high fall risk with only a physical test or a short questionnaire. None of  
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35 296 the fall risk assessment tools identified in this review, which focus on fall history, balance and strength  
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37 297 problems, are able to identify older people with high fall risk adequately. Therefore, other ways of assessing  
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39 298 high fall risk among independently living older people in the primary care setting should be studied. To  
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41 299 improve predictive performance of a fall risk assessment tool, it might help to develop a multi-factorial  
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43 300 assessment tool that also takes a person's behaviour and environment into account.  
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50 302 Overall, the results from this systematic review show that the predictive performance of the six identified  
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52 303 fall risk assessment tools is insufficient. Overall, FH appears to be the same or even better than the other  
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54 304 five fall risk assessment tools. In addition, this tool is most suitable for the primary care setting as it is quick  
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56 305 and does not require equipment, space or training. FH together with a health care professional's clinical  
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58 306 judgement, might be a promising strategy for the primary care setting to identify older people with high  
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3 307 fall risk. When older people with a high fall risk are identified, they can be offered adequate fall preventive  
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5 308 care. This could reduce falls and fear of falling, which might lead to maintained or improved quality of life  
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7 309 and prolonged autonomy of older people.  
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### 13 311 **List of abbreviations**

14 312 GP: General Practitioner

16 313 QUIPS: Quality in Prognosis Study

18 314 AUC: Area Under the Curve

20 315 ROC: Receiver Operating Characteristic

22 316 TUG: Timed-Up-and-Go

24 317 BBS: Berg Balance Scale

26 318 POMA-B: Performance Oriented Mobility Assessment-Balance

28 319 POMA-G: Performance Oriented Mobility Assessment-Gait

30 320 FR: Functional Reach

32 321 FH: Fall History

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### 38 324 **Declarations**

#### 40 325 **Ethics approval and consent to participate**

42 326 Ethics approval is not required for this literature review.

44 327

#### 46 328 **Consent for publication**

48 329 Not applicable.

1  
2  
3 330 **Availability of data and materials**  
4

5 331 The datasets used and/or analysed during the current study are available from the corresponding author  
6  
7 332 on reasonable request.  
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12  
13 334 **Competing interests**  
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15 335 The authors have no conflicts of interests to declare.  
16  
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22

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24  
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26  
27 340 study, data collection, analysis, interpretation, or in the writing of this manuscript.  
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31  
32  
33 342 **Author Contributions**  
34

35 343 WM conducted the systematic review and wrote the manuscript. JK, CL and IG reviewed articles for  
36  
37 344 inclusion, reviewed the quality check, and provided feedback on the manuscript. All authors read and  
38  
39 345 approved the final manuscript.  
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42 346

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45 347 **Acknowledgements**  
46

47 348 Not applicable.  
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560 **Figure Legends**

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562 **Figure 1.** Search keywords

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564 **Figure 2.** Flowchart literature search

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566 **Figure 3.** Eligibility criteria

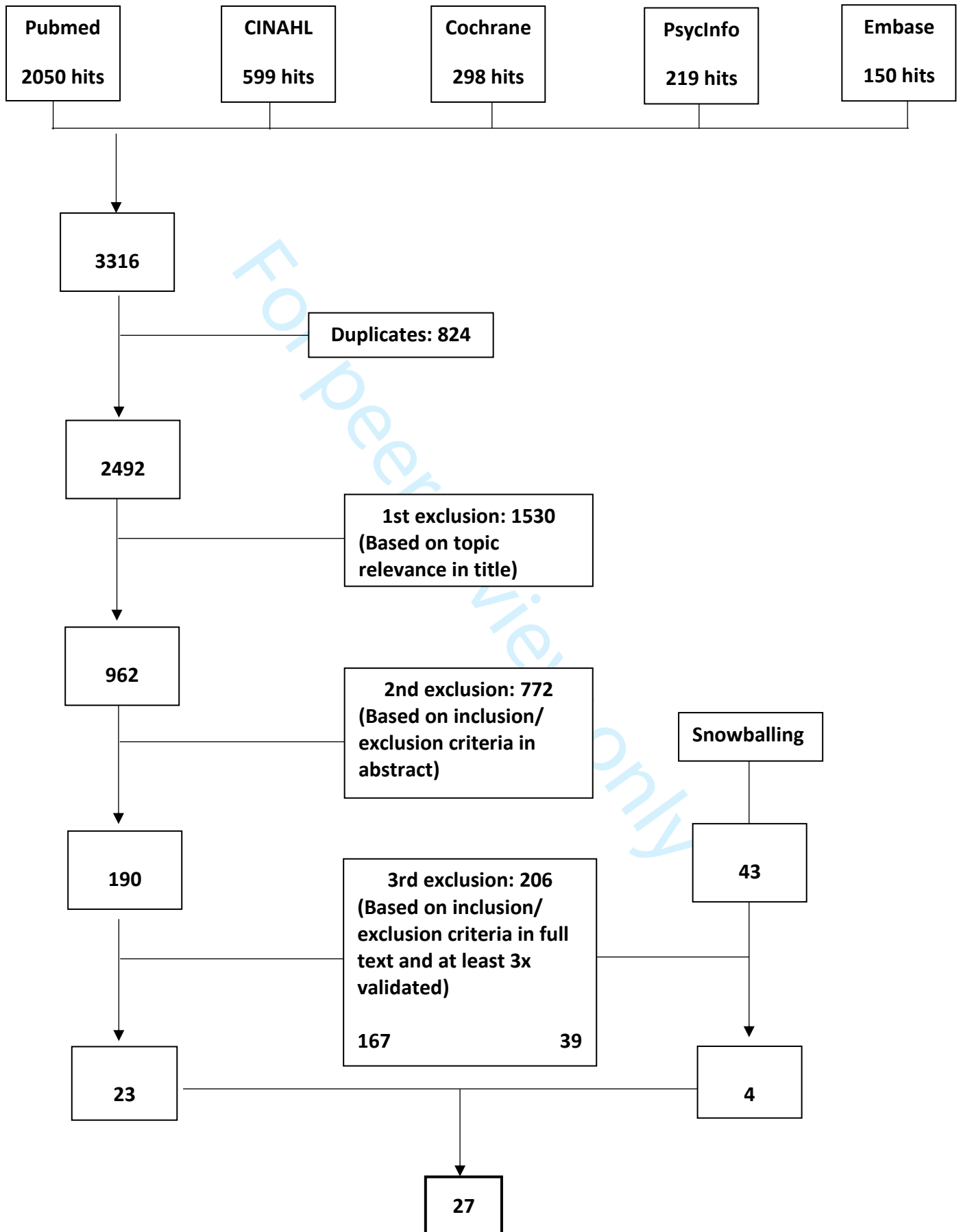
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For peer review only

1 **Figure 1.** Search keywords

2 (Frail Elderly[Mesh] OR Aged[Mesh] OR Frail Elderly\* OR Aged\*)  
3 AND  
4 (Accidental Falls[Mesh] OR Accidental Falls\* OR Falls\*)  
5 AND  
6 (Risk Assessment[Mesh] OR Prognosis[Mesh] OR Diagnosis[Mesh] OR Risk  
7 Assessment\* OR Prognosis\* OR Diagnosis\* OR Screening\* OR Prediction\*)  
8 AND  
9 (Specificity and Sensitivity[Mesh] OR Data Accuracy[Mesh] OR Sensitivity\*  
10 OR Specificity\* OR Accuracy\* OR Validity\*)  
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Figure 2. Flowchart Literature Review



**Figure 3.** Eligibility criteria

Articles were included when they met the following inclusion criteria:

1. Prospective studies in which the primary or secondary purpose was to evaluate the performance of one or more fall risk assessment tools for predicting fallers.
2. The participants were older people living in the community or substantially independently
3. Full articles published in English, Dutch or German

Articles were excluded when they met one or more of the following exclusion criteria:

1. Fall risk assessment tools which require expensive computer software programs, other advanced expensive software or instruments not available in usual primary care units (e.g. sensors, electronical platforms, force plates).
2. Literature reviews and studies with no follow up of fall incidents.
3. No reported Area Under the Curve (AUC), sensitivity or specificity of the fall risk assessment tools.
4. Assessment tools specifically developed for or only tested on populations with a specific disease (e.g. cancer, diabetes, Parkinson etc.)
5. The participants were living in hospital or other institutionalised settings

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### Additional file 1

#### Recent queries in pubmed

Search,Query,Items found,Time

#1,"Search (((("Aged"[Mesh]) OR "Frail Elderly"[Mesh] OR Aged\* OR Frail Elderly\* OR Elderly\*)) AND ("Accidental Falls"[Mesh] OR Accidental Falls\* OR Falls\*)) AND (((Risk Assessment"[Mesh]) OR "Diagnosis"[Mesh]) OR "Prognosis"[Mesh] OR Risk Assessment\* OR Diagnos\* OR Prognos\* OR Screen\* OR Predict\*)) AND (((Sensitivity and Specificity"[Mesh]) OR "Reproducibility of Results"[Mesh]) OR "Data Accuracy"[Mesh] OR Sensitivity\* OR Specificity\* OR Accuracy\* OR Reliab\* OR Valid\*) Filters: Full text

Publication date from 2000/01/01 to 2020/07/01

Field: Title/Abstract,1956,03:40:44

## Additional file 2.

### Overview characteristics included articles

Author	N	Age (range, mean, SD) <sup>1</sup>	Gender	Exclusion	Inclusion	Follow up in months	Included instrument <sup>2</sup>
Alexandre et al., 2012 [29]	60	≥60 (60-82)	29 men/ 31 women	PD, history of transitory ischemic attack, stroke, cognitive impairment, wheelchair, fall in the previous 6 months	n.a.	12 months	TUG test
Bizovska et al., 2018 [48]	131	≥60 (mean 70.8, SD 6.7)	23 men/ 108 women	Any injury or surgery on the musculoskeletal system during the last two years before the baseline measurement	Aged ≥60; ii) no known neurological or musculoskeletal problem that may affect gait or balance abilities; iii) ability to stand and walk without any assistance and assisting device	12 months	POMA-B POMA-G
Bongers et al., 2015 [43]	352	≥70 (mean 76.2 (SD 4.3)	all women	too ill to be screened by GP, currently receiving treatment from geriatrician or received comprehensive geriatric assessment in past 3 months	n.a.	12 months	Gait speed test (4m)
Bongue et al., 2011 [30]	1759	≥65 (65-95, 70.7 (SD 4.6))	862 men/ 897 women	neurological disease, cognitive impairment, unable to understand French or follow simple commands	n.a.	12 months	TUG test
Chow et al., 2019 [42]	192	≥65 (mean: 74.4)	81 men/ 111 women	n.a.	aged ≥65, being discharged from the ED, English speaking, had capacity to give consent, and personally identified a risk factor for falling (if a patient reported that they had either fallen in the last year, worried about falling, or admitted that they felt unsteady when standing or walking)	6 months	TUG test
Coll-Planas et al., 2006 [51]	192 (268 with 76 drop-outs)	≥65 (89 >83 years, 103 ≤83 years)	34 men/ 158 women	living in nursing home	Community dwelling elderly aged ≥65	12 months	Fall history
Ersoy et al., 2009 [47]	125	≥50 (50-79, 61.4 (SD 7.9)	all women	unable to walk without assistance or aids	postmenopausal community dwelling women aged 50+	6 months	BBS

Faber et al., 2006 [49]	72 (total 245)	84.9 (SD 6.0) (of total 245)	14 men/ 58 women	in ability to walk 6m with(out) aids, capacity to understand instructions, medical contraindications to participate, cognitive impairment	n.a.	10 months	POMA-B POMA-G
Gerdhem et al., 2005 [52]	984	75 (75.01-75.99)	all women	n.a.	community dwelling women aged 75 in Malmö	12 months	Fall history
Hofheinz et al., 2016 [31]	120	≥60 (60-87, 72.2 (SD 6.8)	26 men/ 94 women	cognitive limitations, neurological or musculoskeletal diagnose	able to walk 10m with(out) aid, able to understand instructions, able to carry glass in one hand	12 months	TUG test
Kang et al., 2017 [33]	541	≥60 (67.4 (SD 5.6))	234 men/ 307 women	Inability to perform the basic activities of daily living and thus could not complete performance-based assessments; visual impairments; current use of drugs (psychotropic drugs, cardiovascular drugs, hypoglycemic agents, non-steroidal anti-inflammatory drugs, analgesics, dopaminergic drugs, PD's drugs or more than four kinds of complex drugs).	Aged ≥60 years and joined the China's national free physical examination programs	12 months	TUG test Gait speed test (4m)
Kang et al., 2018 [32]	619	≥60 (60-86, 67.4 (SD 5.6))	262 men/ 357 women	Severe functional impairment, current use of sedative drugs, antiepileptic drugs and so on, refusal to participate in the follow-up of this study	Aged ≥60, who joined the free physical examination program	12 months	TUG test
Kojima et al., 2015 [34]	259	≥65 (72.6 (SD 5.9)	95 men/ 164 women	≥3 falls in past year, unstable medical conditions, already exercising 150min/week	aged ≥65 able to walk independently and participate in group exercise	6 months (24 weeks)	TUG test
Lin et al., 2004 [35]	1200	≥65 (73.4 (SD=NR)	709 men/ 491 women	NR	NR	12 months	TUG test FR test
Lindeman et al., 2008 [53]	65	≥65 (67.7 (SD 6.0))	33 men/ 32 women	use of walking aid, self-reported neurological disorders, or spinal or lower extremity joint pain interacting with stepping performance, inability to come to the research department without help, cognitive impairment	community dwelling elderly aged ≥65	12 months	Fall history

1 2 3 4 5 6 7 8 9 10 11 12 13 14	Melzer et al., 2010 [36]	98	≥65 (65-91, 78.4 (SD 5.7))	26 men/ 72 women	serious visual impairment; inability to ambulate independently; cognitive impairment; severe focal muscle weakness or paralysis; severe peripheral or compression/entrapment neuropathies; symptomatic orthostatic hypotension, respiratory, cardiovascular, musculoskeletal or neurological disorders that might have interfered with participation in the exercise program; cancer, metastatic or under active treatment; and use of medication known to impair balance or strength.	n.a.	12 months	TUG test BBS
15 16 17 18	Muir et al., 2008 [46]	187	≥47 (47-90, 79.4 (SD 5.83))	122 men/ 65 women	n.a.	community dwelling veterans of WWII and the Korean War residing in 3 regions of southwestern Ontario	12 months	BBS
19 20 21	Murphy et al., 2003 [50]	50	≥60 (72.3 (SD 8.6))	13 men/ 37 women	no exclusion based on disease	community dwelling elderly aged ≥60	14 months	FR test
22 23 24 25 26	Nitz et al., 2013 [54]	449	≥40 (40-80, 59.3 (SD 10.6))	all women	n.a.	independently mobile and cognitively competent women from the electoral rool in North Brisbane Health district	108 months (9 year)	Fall history
27 28 29 30 31 32 33 34 35 36 37 38 39	Ollsen Möller et al., 2012 [37]	153	≥65 (66-94, 81.5 (SD 6.3))	51 men/ 102 women	n.a.	Age ≥65, living in the municipality where the study was conducted; needing help with at least two activities of daily living (ADL); admitted to hospital at least twice or with at least four contracts with outpatient or primary healthcare during the previous 12 months; being able to communicate verbally and have not cognitive impairments (i.e. ≥25 MMSE)	12 months	TUG test



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Pai et al., 2010 [38]	13	≥65 (65-85, 72 (SD 5))	9 men/ 4 women	musculoskeletal, neurological, cognitive or other systemic disorders, osteopenic or osteoprotic, cognitive impairment, symptomatic postural hypotension	ambulatory community dwelling elderly	9-32 months	TUG test
Russell et al., 2008 [39]	344	≥60 (75.9 (SD 8.5))	106 men/ 238 women	n.a.	community dwelling elderly aged ≥60 presented to an ED as a result of a fall being directly discharged home following emergency care and able to walk independently	12 months	TUG test FR test
Tiedemann et al., 2010 [55]	362	≥74 (74-98, 80.25 (SD=4.5))	128 men/ 234 women	blindness, minimal English language skills, and cognitive impairment	community dwelling elderly aged 63-95 resided in Sydney, Australia	12 months	Fall history
Trueblood et al., 2001 [40]	180	≥60 (60-96, 77.9 (SD 7.26))	37 men/ 143 women	cognitive deficits, underlying neurological problems	aged ≥60, able to stand for 5 min. without aid, able to walk 40 feet at one time without aid.	19 months	TUG test POMA-B POMA-G
Tsutsumimoto et al., 2013 [44]	59	≥65 (Non-fallers 84.0 (SD 1.1) 85.5 (SD 1.4))	11 men/ 48 women	very severe cardiac, pulmonary, musculoskeletal, or neuropathological disorders associated with inability to step safely, cognitive impairment	community-dwelling older people receiving long-term care services aged ≥65, able to walk independently, and having adequate hearing and vision	12 months	Gait speed test (4m)
Verghese et al., 2002 [45]	59	≥65 (Nonfallers 79.7 (SD 6.6) Fallers 79.4 (SD 5.7))	25 men/ 34 women	severe visual loss interfering with completion of neuropsychological tests, non-English or non-Spanish speaking, institutionalization, healthy enough to make a clinic visit	community dwelling elderly aged ≥65	12 months	Gait speed test (4m) POMA-B

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Wrisley et al., 2010 [41]	35	60-90 (72..9 (SD 7.8))	17 men/ 18 women	cognitive impairment, history of osteoporosis, recent fractures, or lower-extremity surgery; history of progressive neuromuscular disorder; history of whiplash, neck injury, or current complaints of neck pain; history of unstable agina or uncontrolled cardiorespiratory problems; taking any medications that might affect balance; history of any fall in past 6 months and more than one fall in the last year; pain in any segment greater than 2/10 on a 10-point verbal analog scale; not returning the monthly fall calendar	community dwelling elderly aged 60-90 able to stand independently longer than 1 min.	months	TUG test
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<sup>1</sup> range, mean, SD: only described when reported in included article

<sup>2</sup> TUG test: Timed Get Up and Go test

POMA- B: Performance Oriented Mobility Assessment –Balance

POMA-G: Performance Oriented Mobility Assessment –Gait

BBS: Berg Balance Scale

FR test: Functional Reach test



# PRISMA 2009 Checklist

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Section/topic	#	Checklist item	Reported on page #
<b>TITLE</b>			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	Title, page 1
<b>ABSTRACT</b>			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	Abstract, page 2
<b>INTRODUCTION</b>			
Rationale	3	Describe the rationale for the review in the context of what is already known.	Background, page 3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	PICO: Background, page 3 S: Methods, Analysis/Figure 3
<b>METHODS</b>			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	N/A
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g. years considered, language, publication status) used as criteria for eligibility, giving rationale.	Methods, Figure 3
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	Methods, Study selection
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Methods, Figure 1
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	Methods, Eligibility criteria and study selection
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	Methods, Eligibility



# PRISMA 2009 Checklist

			criteria and study selection
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	Methods, Analysis
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	Methods, Quality appraisal
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	N/A
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I <sup>2</sup> ) for each meta-analysis.	N/A

Page 1 of 2

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	N/A
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
<b>RESULTS</b>			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Methods, Figure 2
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Additional File 2
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Results, Table 1
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	N/A
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	N/A
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	N/A
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
<b>DISCUSSION</b>			



# PRISMA 2009 Checklist

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Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	Discussion, page 8-10
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	Discussion, Limitations
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	Discussion, page 8-10
<b>FUNDING</b>			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data), role of funders for the systematic review.	Declarations, Funding

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

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# BMJ Open

## A practical and validated tool to assess falls risk in the primary care setting: A systematic review

Journal:	<i>BMJ Open</i>
Manuscript ID	bmjopen-2020-045431.R2
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Date Submitted by the Author:	15-Jul-2021
Complete List of Authors:	Meekes, Wytske; Tilburg University Tranzo Scientific Centre for Care and Welfare, Korevaar, J; NIVEL Leemrijse, Chantal; NIVEL Van de Goor, Ien ; Tilburg University Tranzo Scientific Centre for Care and Welfare
<b>Primary Subject Heading</b>:	General practice / Family practice
Secondary Subject Heading:	Public health
Keywords:	GENERAL MEDICINE (see Internal Medicine), PRIMARY CARE, PREVENTIVE MEDICINE, PUBLIC HEALTH

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5 1 **A practical and validated tool to assess falls risk in the primary care setting: A**  
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8 2 **systematic review**  
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10 3 Wytse M.A. Meekes<sup>1\*</sup>, Joke C. Korevaar<sup>2</sup>, Chantal J. Leemrijse<sup>2</sup>, Ien A.M. van de Goor<sup>1</sup>

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## 16 Abstract

17 **Objective:** Although several falls risk assessment tools are available, it is unclear which have been validated  
18 and which would be most suitable for primary care practices. This systematic review aims to identify the  
19 most suitable falls risk assessment tool for the primary-care setting (i.e. requires limited time, no expensive  
20 equipment and no additional space) and that has good predictive performance in the assessment of falls  
21 risk amongst older people living independently.

22 **Design:** A systematic review based on prospective studies.

23 **Methods:** An extensive search was conducted in the following databases: PubMed, EMBASE, CINAHL,  
24 Cochrane and PsycINFO. Tools were excluded if they required expensive and/or advanced software that is  
25 not usually available in primary-care units and if they had not been validated in at least three different  
26 studies. Of 2,492 articles published between January 2000 and July 2020, 27 were included.

27 **Results:** Six falls-risk assessment tools were identified: Timed Up and Go test, Gait Speed test, Berg Balance  
28 Scale, Performance Oriented Mobility Assessment, Functional Reach test and falls history. Most articles  
29 reported AUC values ranging from 0.5 to 0.7 for these tools. Sensitivity and specificity varied substantially  
30 across studies (e.g. TUG, sens.:10-83.3%, spec.:28.4-96.6%).

31 **Conclusions:** Given that none of the falls risk assessment tools had sufficient predictive performance  
32 (AUC<0.7), other ways of assessing high falls risk amongst independently living older people in primary care  
33 should be investigated. For now, the most suitable way to assess falls risk in the primary care setting  
34 appears to involve asking patients about their falls history. Compared to the other five tools, the falls  
35 history requires the least amount of time, no expensive equipment, no training, and no spatial adjustments.  
36 The clinical judgement of healthcare professionals continues to be most important, as it enables the  
37 identification of high falls risk even for patients with no falls history.

38  
39 **Key words:** Falls prevention, Falls risk assessment tools, Predictive Performance, Primary Care, Review

## Strengths and Limitations of this study

- This review is built on extensive literature regarding falls risk assessment tools that are suitable for the primary care setting and representations of their predictive performance.
- We endeavoured to reduce bias by only including falls risk assessment tools that have been validated at least three times in different studies and by assessing the risk of bias.
- Given that different studies used different cut-off scores, addressed modified versions of the same tools and presented different outcome measures, it was difficult to combine the results and reach a convincing conclusion.

## 52 Introduction

53 Worldwide, falls are the second leading cause of accidental or unintentional injury deaths [1]. On average,  
54 one of every three people aged 65 years or older falls at least once a year [2], and an estimated 646,000  
55 people die each year due to the consequences of falls [1]. These numbers are increasing as society ages  
56 [3]. The consequences of falls can range from scratches or bruises to hip fractures, brain injuries or even  
57 death [4, 5]. Falls can have a major, long-lasting negative impact on the quality of life and self-management  
58 of older people [4-6]. The treatment and rehabilitation of falls incidences are correlated with high costs in  
59 the healthcare sector [5, 7]. Therefore, the provision of falls prevention is important for older people.

60 Society is ageing, and older people are living independently at home for longer [3]. The first point of contact  
61 for health problems is the general practitioner (GP). The approaches adopted by GPs vary, with some  
62 providing no falls prevention care at all, while others are quite active with regard to falls prevention. Given  
63 that only 20% of all older patients inform their GPs about their falls, GPs are unaware of the occurrence of  
64 80% of the falls amongst their patients [8, 9], and they are thus likely not to know which of their patients  
65 are at risk of falls. This situation results in a delay or lack of treatment for falls risk amongst older people,  
66 despite the availability of potentially effective falls prevention interventions [10-14].

67 The early identification of high falls risk amongst older people is a prerequisite to providing adequate care  
68 in time to reduce the risk of falls. Many tools are available for assessing falls risk, including the Timed Up  
69 and Go (TUG) test, the Tinetti Balance, the Berg Balance Scale (BBS) and the American Geriatrics  
70 Society/British Geriatrics Society guidelines for clinical practice. In a previous review, Gates et al. (2008)  
71 summarise the accuracy of tools for predicting the risk of falling amongst older adults living in communities.  
72 They conclude that there is insufficient evidence to show that any instrument was adequate for predicting  
73 falls and they neither report nor consider implications for practice. It thus remains unclear which falls risk  
74 assessment tools have good predictive performance and might be suitable for practice.

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3 76 The high workload associated with primary care places constraints on the time of practitioners [15, 16].  
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5 77 They also have limited resources for expensive equipment (e.g. platforms, sensors), and their practices  
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7 78 generally have little space [17-20]. A suitable falls risk assessment tool for primary care settings should  
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9 79 therefore require limited time, no expensive equipment and no space adjustments. This systematic review  
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11 80 aims to identify falls risk assessment tools that are the most suitable for primary care (i.e. quick [<5 min],  
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13 81 no expensive equipment or specific resources required) and that have demonstrated good predictive  
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15 82 performance in assessing the risk of falls amongst older people living independently. In this study, an  
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17 83 assessment tool is understood as a tool that defines the nature of a specific problem: whether a patient  
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19 84 does or does not have a high risk of falls [21]. No additional assessment is required to identify high or low  
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21 85 falls risk. Additional assessment is needed only to explore which intervention is needed to reduce a  
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23 86 patient's risk of falls.  
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## 30 88 **Methods**

### 31 89 **Study selection**

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34 90 A systematic literature search was conducted in the following databases: PubMed, EMBASE, CINAHL,  
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36 91 Cochrane and PsycINFO, using the search keywords presented in Figure 1 (see Additional File 1). Mesh  
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38 92 terms were used when possible. Additional articles were included after snowballing. The flowchart for the  
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40 93 literature search is displayed in Figure 2.  
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48 95 **Figure 1.** Search keywords  
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52 97 **Figure 2.** Flowchart for the literature search  
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### 54 98 **Eligibility criteria and study selection**

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58 100 The proportion of older people is increasing, and the current population of older people is ageing  
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60 101 differently than was the case 20 years ago (e.g. people are becoming older and are more vulnerable to

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3 102 chronic diseases) [22, 23]. Given the importance of validating suitable falls risk assessment tools in the  
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5 103 current population of older people, the review included articles published between January 2000 and July  
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7 104 2020 that met the criteria for inclusion (as presented in Figure 3).  
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10 105 This review includes only prospective studies, thus making it possible to summarise the predictive  
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12 106 performance of falls risk assessment tools [24]. In addition, our final analysis includes only tools that have  
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14 107 been assessed in at least three different studies. This was done in order to ensure the validity of the tools  
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16 108 that were included, as studies are likely to differ (e.g. in terms of the age, sex or frailty of the selected  
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18 109 population).  
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22 110 The first round of exclusion based on title was performed by WM. All articles from the second round of  
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24 111 exclusion based on abstract were reviewed by WM. In addition, JK, CL and IG each reviewed 67 articles  
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26 112 from a sample of 200 articles from the second round of exclusion. Given the high level of agreement  
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28 113 between the reviewers, only the sample of 200 articles was reviewed independently by two reviewers to  
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30 114 identify differences in scoring. For the third round of exclusion, WM reviewed all full texts, with JK, CL and  
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32 115 IG each reviewing one third of all full texts. Differences between reviewers were discussed until consensus  
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34 116 was reached. In total, 26 articles were included in this study.  
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### 39 40 118 **Quality appraisal**

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42 119 The quality of the included studies was assessed independently by two reviewers (WM, together with JK,  
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44 120 CL or IG) using the Quality in Prognosis Studies (QUIPS) tool [25, 26]. Articles were classified as being of low  
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46 121 quality (\*), referring to high potential bias; moderate quality (\*\*), referring to moderate potential bias; or  
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48 122 high quality (\*\*\*), referring to low potential bias. The reviewers resolved differences through discussion  
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50 123 until consensus was reached.  
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54 124 **Figure 3.** Eligibility criteria  
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## 126 **Analysis**

127 This review investigates the predictive performance of prognostic tests for predicting the likelihood of  
128 experiencing a fall. The predictive performance of a prognostic test is often described similarly to that of  
129 diagnostic tests, based on diagnostic accuracy [24]. In this review, diagnostic accuracy refers to the ability  
130 to discriminate accurately between fallers and non-fallers according to various measures, including  
131 sensitivity, specificity and area under the curve (AUC) [27]. To this end, data regarding sensitivity, specificity  
132 and AUC were extracted from the articles and described.

133 Sensitivity refers to the ability to classify individuals correctly as being at risk of falls, and specificity refers  
134 to the ability to classify individuals correctly as not being at risk of falls [28]. A diagnostic test has good  
135 predictive value if sensitivity and specificity are >70% [29]. The AUC is the area under the receiver operating  
136 characteristic (ROC) curve, which represents the accuracy of the test. The ROC curve can be used to select  
137 the best cut-off score for most optimal sensitivity and specificity, with greater AUC reflecting a better test.  
138 The accuracy of a diagnostic test is considered good or excellent if the AUC is >0.7 [27]. We ranked the  
139 outcomes, taking into account the cut-off values for good sensitivity, specificity and AUC [27, 29].

140 When analysing the results, we also considered criteria regarding the suitability of falls risks assessment  
141 tools for the primary care setting. The time available to primary healthcare providers is limited, due to their  
142 high workload [15, 16, 19, 20]. They also have limited resources for expensive equipment (e.g. platforms,  
143 sensors), and their practices generally have little space [17, 18]. When analysing the results, we therefore  
144 considered the following criteria for a suitable tool: limited time, no expensive equipment and no spatial  
145 adjustments.

146

## 147 **Patient and public involvement**

148 Before conducting the systematic review, an informal focus group was conducted with primary care  
149 professionals (4 GPs, 2 practice nurses and 3 district nurses)—the end-users—to identify their needs and  
150 wishes regarding falls risk assessment tools. We used the results of this informal focus group, together with  
151 previous literature, to define the suitability criteria used in this study. This ensured that the perspective of

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3 152 primary care professionals was taken into account when analysing the results of the review. No patients  
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5 153 were directly involved in this systematic review.  
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## 11 155 **Results**

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14 156 The 27 articles included in this review identify a total of six falls risk assessment tools. Each of these tools  
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16 157 is described below and presented in Table 1. Further details about the included articles are provided in  
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18 158 Additional File 2.

### 21 159 *Timed Up and Go test*

22  
23 160 The Timed Up and Go (TUG) test takes only a few minutes to complete, and it was described in 14 studies  
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25 161 [30-43]. In this test, participants are asked to stand up from a chair, walk three metres, turn, walk three  
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27 162 metres back and sit down again. The time taken to perform this task indicates high or low falls risk. The  
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29 163 cut-off scores reported in the articles varied from 10.9 to 13 seconds. The AUC is described in 11 studies,  
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31 164 ranging from 0.46 to 0.89. In eight studies, sensitivity ranges from 10% to 83.3%, and specificity ranges  
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33 165 from 28.4% to 96.6%.  
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### 37 166 *Gait Speed test*

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39 167 The Gait Speed test, based on a distance of four metres, takes only a few minutes to complete, and it is  
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41 168 evaluated in four studies [34, 44-46]. In this test, participants are asked to walk four metres at their usual  
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43 169 pace. The time taken to complete the task is recorded, and gait speed is calculated (m/s). An AUC value of  
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45 170 0.5 is reported by Bongers et al. [44], and a value of 0.77 is reported by Tsutsumimoto et al. [45]. In an  
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47 171 investigation of AUC for different follow-up periods and for any or recurrent falls, Kang et al. [34] report  
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49 172 values ranging from 0.54 to 0.68. Sensitivity and specificity were reported in two studies [45, 46], ranging  
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51 173 from 38.4% to 100% and from 23.9% to 84.7%, respectively, depending on the cut-off scores.  
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### 54 174 *Berg Balance Scale*

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57 175 The Berg Balance Scale (BBS) evaluates a participant's balance based on 14 items scored along a five-point  
58  
59 176 Likert scale and takes 15–20 minutes to complete. The score for each item ranges from 0 to 4 points, with  
60

177 **Table 1.** Falls risk assessment tools included in this review

Tools	Authors and year	Suitability	N	Cut-off score <sup>1</sup>	AUC (95%CI)	Sens	Spec	Quality <sup>2</sup>	
Timed Up and Go test	Alexandre et al., 2012 [23]	Time: <5min.	60	12.47 s	0.68 (0.54-0.83)	0.73	0.658	**	
	Bongue et al., 2011 [24]		1759	10.9 s	0.54 (0.52-0.57)			**	
	Hofheinz et al., 2016 [25]	Space: ±4 m.	120		0.58			**	
	Kang et al. 2018 [26]		541	any falls	0.607 (0.549-0.665)		0.563	**	
	Tools: Stopwatch, chair, tape-measure	any falls		0.642 (0.584-0.700)					
		recurrent falls		0.688 (0.602-0.773)					
		10.15s, recurrent falls		0.733 (0.645-0.821)	0.675				
	Kang et al., 2017 [27]	Training required: Yes	619	>10.2 s	0.603 (0.545-0.661)			**	
	Kojima et al., 2015 [28]		259	12.6 s	0.58	0.305	0.895	**	
	Lin et al., 2004 [29]		1200		0.61			**	
	Melzer et al., 2010 [30]		98		0.57			***	
	Ollsen Möller et al., 2012 [31]		153	≥12-13s at 6 months follow up			0.67	0.50	*
				≥12-13s at 12 months follow up			0.78		
	Pai et al., 2010 [32]		13		0.46	0.50 (0.09-0.91)	0.56 (0.40-0.96)	**	
Russel et al., 2008 [33]		344		0.63 (0.57-0.69)			**		
Trueblood et al., 2001 [34]		180			0.1	0.95	**		
Wrisley et al., 2010 [35]		35	12.34 s	0.89	0.833	0.966	***		
Chow et al., 2019 [36]		192	12 s	0.54	0.706 (0.562-825)	0.284 (0.211-0.366)	**		
Gait speed test (4m)	Kang et al., 2017 [27]	Time: <5 min.	541	any falls	0.563 (0.504-0.622)			**	
				any falls	0.586 (0.526-0.647)				
		recurrent falls		0.542 (0.445-0.639)					
		recurrent falls		0.680 (0.593-0.768)					
	Space: ± 5 m.	Tools: Stopwatch, tape-measure	352		0.5			**	
			59	0.67m/s	0.77 (0.62-0.92)	0.82	0.71	**	
Verghese et al., 2002 [39]	Training required: Yes	59	≥12 s			1	0.239	***	
			≥14 s			0.769	0.565		
			≥18 s			0.384	0.847		
Berg Balance Scale	Melzer et al., 2010 [30]	Time: 15-20 min.	98	≤52	0.47			***	
	Muir et al., 2008 [40]	Space: ± 1-2 m.	187	≤53 (multiple falls)	0.68	0.69 (0.50-0.83)	0.57 (0.47-0.66)	**	
				≤54 (any fall)	0.59	0.61 (0.50-0.72)	0.53 (0.43-0.63)		

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				≤45 (multiple falls)		0.42 (0.26-0.61)	0.87 (0.79-0.92)	
				≤45 (any falls)		0.25 (0.16-0.36)	0.87 (0.79-0.92)	
	Ersoy et al., 2009 [41]	Tools: Stopwatch, 2 chairs, tape-measure, step bench	125	≤48		0.686	0.756	*
		Training required: Yes						
Performance Oriented Mobility Assessment - Balance	Trueblood et al., 2001 [34]	Time: ± 10 min.	180	10		0.24	0.91	**
	Vergheze et al., 2002 [39]	Space: ± 1-2 m.	59	≤8		0.076	0.913	***
				≤9		0.23	0.804	
				≤10		0.615	0.695	
	Bizovska et al., 2018 [42]	Tools: chair without handrails	131	(multiple fallers)	0.659	0.89	0,47	**
Faber et al., 2006 [43]	Training required: Yes	72	10		0.640 (0.445-0.798)	0.661 (0.530-0.771)	**	
Performance Oriented Mobility Assessment -Gait	Trueblood et al., 2001 [34]	Time:±10 min.	180	9		0.21	0.95	**
	Bizovska et al., 2018 [42]	Space: ± 1-2 m.	131		NR because NS			**
	Faber et al., 2006 [43]	Tools: obstacle-free corridor or space	72	9		0.640 (0.445-0.798)	0.625 (0.494-0.74)	**
		Training required: Yes						
Functional Reach test	Lin et al., 2004 [29]	Time: <5 min.	1200		0.509			**
	Russel et al., 2008 [33]	Space: ± 1-2 m.	344		0.60 (0.54-0.66)			**
	Murphy et al., 2003 [44]		50	8in.		0.73	0.88	*
		Tools: Tape-measure						
		Training required: Yes						
Falls History	Coll-Planes et al., 2006 [45]		192	≥1 fall(s) in previous year		0.595	0.645	**
	Gerdhem et al., 2005 [46]		984	1 fall in previous year		0.39	0.82	**
				≥2 falls in previous year compared to ≤ 1 fall		0.46	0.8	
	Lindemann et al., 2008 [47]		65	≥1 fall(s) in previous year		0.63	0.77	**
	Nitz et al., 2013 [48]		449	History of multiple falls	0.64			**
	Tiedemann et al., 2010 [49]		362	≥1 fall(s) in previous year	0.71		0.69 (0.57-0.78)	0.63 (0.57-0.69)

178 <sup>1</sup>s: seconds / m: meters / in: inch<sup>2</sup>Quality assessed with QUIPS tool: \* High bias, \*\* Moderate Bias, \*\*\* Low Bias

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2  
3 179 an overall maximum score of 56 points. Balance is evaluated by asking participants to perform a variety of  
4  
5 180 sitting, transferring and standing positions. In an assessment of which cut-off scores on the BBS best predict  
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7 181 the risk of falling, Muir et al. [47] distinguish between single and multiple falls. They report an AUC of 0.68  
8  
9 182 for multiple falls with a cut-off score  $\leq 53$ , and an AUC of 0.59 for a single fall with a cut-off score  $\leq 54$ . A  
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11 183 lower value of 0.47 is reported by Melzer et al. [37]. Sensitivity and specificity are reported in studies by  
12  
13 184 Muir et al. [47] (25%–69%) and by Ersoy et al. [48] (53%–87%).

#### 16 17 185 *The Tinetti tests*

18  
19 186 The Tinetti tests are widely used tests for assessing the risk of falling, but there are many variations. One is  
20  
21 187 the Performance Oriented Mobility Assessment (POMA) Total, which consists of two components to assess  
22  
23 188 balance (POMA-B) and gait (POMA-G) and takes about 20 minutes to complete. For the POMA-B test, which  
24  
25 189 is assessed in four studies [41, 46, 49, 50], participants are asked to perform nine different movements to  
26  
27 190 assess balance. Depending on the cut-off scores, sensitivity ranges from 23% to 89%, with specificity  
28  
29 191 ranging from 47% to 91.3%. An AUC of 0.66 is reported by Bizovska et al. [49], but no cut-off scores are  
30  
31 192 specified, and the comparison concerns multiple falls, thus excluding single falls. In the POMA-G,  
32  
33 193 participants are asked to perform six different movements to assess gait. It is recommended to conduct  
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35 194 this test in a corridor. The only study to specify the space used for the test is by Bizovska et al. [49]: a well-lit  
36  
37 195 corridor with a length of 30 metres. Faber et al. [50] and Trueblood et al. [41] report sensitivities ranging  
38  
39 196 from 21% to 64% and specificities ranging from 63% to 95%. Bizovska et al. [49] do not report any specific  
40  
41 197 results, as they found no significant differences between fallers and non-fallers in relation to the POMA-G.

#### 44 45 198 *The Functional Reach test*

46  
47 199 The Functional Reach (FR) test is validated in three studies [36, 40, 51]. In this test, participants are asked  
48  
49 200 to hold their arms in front of them in an angle of 90 degrees, stretch forward as far as possible and return  
50  
51 201 to the starting position. The distance between the starting position and the stretched position is used as  
52  
53 202 an indicator of the risk of falling. This test takes less than five minutes to complete. The AUC is reported in  
54  
55 203 two studies [36, 40], varying from 0.51 to 0.60. Murphy et al. [51] mention a sensitivity of 73% and a  
56  
57 204 specificity of 88%.

### 205 *Falls History*

206 Five studies explore the accuracy of falls history (FH) [52-56], which takes only a few minutes to assess.

207 These five studies apply different definitions of FH, with the most common being at least one fall in the

208 previous year. Tiedemann et al. [56] and Nitz et al. [55] report AUC values ranging from 0.64 to 0.71.

209 Sensitivity and specificity are explored in four studies, with sensitivity ranging from 39% to 69% and

210 specificity ranging from 63% to 82%.

### 211 *Quality Appraisal*

212 The methodological quality of all articles was assessed (see Table 1). Three articles were classified as high

213 quality, 21 articles as moderate quality and three articles as low quality.

214

## 215 **Discussion**

### 216 **Discussion**

217 This study aimed to identify falls risk assessment tools that are suitable for the primary care setting (i.e.

218 they require limited time, no expensive equipment and no additional space) and that have good predictive

219 performance in assessing the risk of falling amongst older people who are living independently. This

220 systematic review identifies six falls risk assessment tools for the primary care setting. The vast majority of

221 the included studies identify the falls risk amongst older people over a period of 12 months (mean: 15

222 months; minimum: 6 months; maximum: 9 years; see Additional File 2). None of these tools appears to be

223 adequate in discriminating between people who are and are not at high risk of falling, taking into account

224 the thresholds for good diagnostic accuracy (AUC>0.7), as proposed by Šimundić [27]. These findings do

225 not change when considering only the articles of moderate and high quality. Four studies report AUC values

226 >0.7 for the TUG test [33, 42], Gait Speed test [45] and FH[56], thereby indicating good diagnostic accuracy

227 [27]. In most of the articles, however, the AUC values range from 0.5 to 0.7, thus indicating insufficient

228 diagnostic accuracy for all of the tools addressed. Furthermore, the sensitivity and specificity of the same

229 tool varied substantially across studies. We are therefore unable to draw convincing conclusions.

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2  
3 230 The results of this review are corroborated by other studies. For example, even though the TUG test is  
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5 231 widely used to assess falls risk, other studies have also reported a lack of predictive ability for this test with  
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7 232 regard to falls [57, 58]. Furthermore, as stated by Gates et al. [59], 'At present, recommending any  
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9 233 screening test for routine clinical use is not possible. Despite the number of studies that have been  
10  
11 234 conducted, no strong evidence exists that any screening test is useful for identifying fallers'. [58, p1113-  
12  
13 1114]. The current systematic review, conducted 13 years later, leads to the same conclusion. The lack of  
14 235  
15 236 conclusive evidence to identify falls risk assessment tools with adequate predictive performance and  
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17 237 accuracy persists to date. It is therefore impossible to select an assessment tool based on predictive  
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19 238 performance. Our review nevertheless adds valuable information to the existing body of literature  
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21 239 concerning the tool that is currently most suitable for use by primary care providers to identify patients  
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23 240 who are at high risk of falls.

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27 241 Primary health care providers have limited time and lack resources for expensive equipment, space and  
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29 242 training [15-20]. In light of these constraints, the results of this study suggest that the most suitable tool is  
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31 243 FH, as it takes only a few minutes to conduct and requires no training, expensive equipment or spatial  
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33 244 adjustments. The BBS and the Tinetti tests would not be suitable, as they take 15–20 minutes to complete  
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35 245 and require training to conduct. The TUG and Gait Speed tests are both quick (< 5min.), but they require  
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37 246 training and space (>4 metres) to conduct. Although the FR test is quick (< 5min.) and does not require  
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39 247 much space, it requires more training than FH and the AUC values reported are lower than those for FH.

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43 248 Despite the fact that it is insufficient, the diagnostic accuracy of FH is the same or even better than that of  
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45 249 most of the other five falls risk assessment tools (see Table 1). Based on the clinometric evaluation of four  
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47 250 falls risk assessment tools, Barker et al. [60] also identify FH as a suitable assessment tool, stating that 'the  
48  
49 251 predictive validity of all tools was found to be low, with no tool offering greater ability to identify residents  
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51 252 who would fall than a simple screening question "has the resident fallen in the past 12 months?" [59, p919].  
52  
53 253 Patient FH is also used in many multifactorial assessment tools and algorithms, and it appears to be an  
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55 254 important factor in the risk of falling (OR: NS-14.02) [48, 53, 55, 61-68]. The use of FH nevertheless  
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57 255 eliminates the possibility of identifying first-time fallers. Although this is clearly a major disadvantage, older  
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3 256 people might be less willing to start and complete falls prevention interventions if they have not previously  
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5 257 experienced a fall. They often do not consider themselves at high risk of falling [69, 70]. The experience of  
6  
7 258 a previous fall might therefore enhance motivation to start and complete a falls prevention intervention  
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9 259 [71].

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12 260 According to a study by Nordin et al. [72], the assessment of falls risk through the combination of clinical  
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14 261 judgement and FH amongst a population of frail older people was superior to performance-based  
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16 262 measures. Meyer et al. [73] even assert that the use of falls risk assessment tools should be avoided, 'since  
17  
18 263 it has no clinical consequences other than the waste of scarce nursing resources' [72, p421]. Due to  
19  
20 264 increasing work pressure [15-18] and lack of awareness [74, 75], healthcare professionals might not assess  
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22 265 a patient's risk of falling based solely on clinical judgement, as it is not part of any systematic assessment  
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24 266 strategy. The systematic assessment of falls risk by combining FH and the expertise of healthcare  
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26 267 professionals might therefore be an adequate strategy.

### 27 28 29 30 268 **Practice recommendations**

31  
32 269 In daily practice, GPs can ask their older patients during consultation if they have had a fall during the past  
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34 270 12 months. Even if a patient has not had a fall, the GP might still identify a high falls risk based on clinical  
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36 271 judgement (e.g. walking or sitting difficulties due to strength and balance problems, dizziness, use of  
37  
38 272 benzodiazepines, visual impairment). If a high falls risk is suspected after such a brief assessment, the GP  
39  
40 273 could investigate the underlying cause of the falls risk by conducting a multifactorial assessment so that  
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42 274 adequate care can be provided. It should be noted that, in this study, FH is defined as an assessment tool  
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44 275 and not as a screening tool. A falls risk assessment tool defines the nature of the problem, and thus whether  
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46 276 a patient is or is not at high risk of falling [21]. No additional assessment is required to identify high or low  
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48 277 falls risk. Additional assessment (e.g. multifactorial assessment) is needed only to determine which  
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50 278 intervention is needed in order to reduce a patient's high falls risk. Screening tools are intended to evaluate  
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52 279 the possible presence of specific problems. A screening tool would require additional assessment in order  
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54 280 to verify that a patient has a high falls risk [21].  
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3 281 Depending on the organisation of the GP practice, the GP could also refer the patient to another healthcare  
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5 282 provider (e.g. a practice nurse specialised in geriatric care), who might have more time to investigate the  
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7 283 underlying cause of the falls risk. A patient's falls risk could be reduced by conducting a brief falls risk  
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9 284 assessment that leads to a comprehensive multifactorial assessment to identify the underlying causes,  
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11 285 followed by multifactorial interventions that address any risk factors that have been identified [76-78]. The  
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13 286 clinical practice guidelines of the American Geriatrics Society/British Geriatrics Society recommend  
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15 287 conducting falls risk assessments annually [79].  
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### 289 **Strengths and Limitations**

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24 290 This review was not registered at PROSPERO, the international prospective register of systematic reviews.  
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26 291 This could have caused duplication of review topics. Nonetheless, no ongoing reviews were found in the  
27  
28 292 PROSPERO register that specifically focus on suitability of falls risk assessment tools for the primary care  
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30 293 setting.  
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33 294 In this review, the initial screening of titles and abstracts was performed by one researcher (WM). For the  
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35 295 second round of selection, a sample of 200 articles was reviewed independently by a second researcher  
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37 296 (JK, CL or IG), based on abstract (>95% consensus). Even though this is an acceptable procedure according  
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39 297 to the Cochrane Handbook for Systematic Reviews of Interventions, each screening step should ideally be  
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41 298 performed by at least two people working independently [80]. Our results might therefore be subject to  
42  
43 299 bias due to our method of study selection.  
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47 300 The results of this review were difficult to combine. Different studies used different cut-off scores,  
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49 301 addressed modified versions of the same tests and presented different outcome measures. These  
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51 302 differences between studies made it difficult to arrive at a convincing conclusion based on the results.  
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54 303 Given that we have included at least three studies for each tool, it would seem feasible to conduct a meta-  
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56 304 analysis for each tool. We did not do this, however, for two reasons. First, the diversity between studies  
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58 305 assessing the same tools was quite high. For example, there were substantial differences in cut-off scores,  
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3 306 follow-up periods and study populations (e.g. in terms of sex, age), as well as in the criteria for inclusion  
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5 307 and exclusion and the quality of the studies. These differences rendered a meta-analysis unsuitable for  
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7 308 most tools. Second, the results of our study are clear without conducting a meta-analysis: none of the six  
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9 309 tools identified in the review appears to be adequate in discriminating between people who are and are  
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11 310 not at high risk of falling, taking into account the thresholds for good diagnostic accuracy (AUC>0.7), as  
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13 311 proposed by Šimundić [27]. Another limitation is related to the possibility of publication bias against studies  
14  
15 312 with worse outcomes, which might have led to an overestimation of the predictive performance of the falls  
16  
17 313 risk assessment tools that were included. All of these limitations support our conclusion that none of the  
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19 314 tools addressed has sufficient predictive performance.

### 23 315 Further Research

24  
25 316 The underlying cause of falls is often multi-factorial and complex. This makes it difficult, if not impossible  
26  
27 317 to adequately identify people who are at high risk of falling using only a physical test or brief questionnaire.  
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29 318 None of the falls risk assessment tools identified in this review, all of which focus on falls history, balance,  
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31 319 gait and/or strength problems, is capable of adequately identifying older people with high falls risk. It is  
32  
33 320 therefore important to investigate other ways of assessing high falls risk in the primary care setting  
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35 321 amongst older people who are living independently. The predictive performance of falls risk assessment  
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37 322 tools could potentially be enhanced by developing a multi-factorial assessment tool that also takes into  
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39 323 account a person's behaviour and environment.

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42  
43 324 Taken together, the results of this systematic review indicate that the predictive performance of the six  
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45 325 falls risk assessment tools identified in the studies reviewed is insufficient. Overall, FH appears to be the  
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47 326 same or even better than the other five tools. In addition, this tool is most suitable for the primary care  
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49 327 setting, as it is quick and does not require equipment, space or training. The combination of FH and the  
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51 328 clinical judgement of a healthcare professional could be a promising strategy in the primary care setting  
52  
53 329 for identifying older people who are at high risk of falling, such that they can be provided with adequate  
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55 330 falls prevention care. This could reduce both falls and fear of falling, thereby maintaining or improving  
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57 331 quality of life and prolonging autonomy for older people.  
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3 332 **List of abbreviations**

4 333 GP: General Practitioner

6 334 QUIPS: Quality in Prognosis Study

8 335 AUC: Area Under the Curve

10 336 ROC: Receiver Operating Characteristic

12 337 TUG: Timed Up and Go

14 338 BBS: Berg Balance Scale

16 339 POMA-B: Performance Oriented Mobility Assessment-Balance

18 340 POMA-G: Performance Oriented Mobility Assessment-Gait

20 341 FR: Functional Reach

22 342 FH: Falls History

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28 345 **Declarations**

30 346 **Ethics approval and consent to participate**

32 347 No ethics approval was required for this literature review.

34 348

36 349 **Consent for publication**

38 350 Not applicable.

40 351 **Availability of data and materials**

42 352 The datasets used and/or analysed during the current study are available from the corresponding author

44 353 on reasonable request.

46 354

48 355 **Competing interests**

50 356 The authors have no conflicts of interests to declare.



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3 357  
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12 361 of the study, the collection, analysis or interpretation of data, or the writing of this manuscript.  
13  
14

15 362  
1617  
18 363 **Author Contributions**  
19

20 364 WM conducted the systematic review and wrote the manuscript. JK, CL and IG reviewed articles for  
21  
22 365 inclusion, reviewed the quality check and provided feedback on the manuscript. All authors read and  
23  
24 366 approved the final manuscript.  
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27  
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32  
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3 585 **Figure Legends**

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6 587 **Figure 1.** Search keywords

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10 589 **Figure 2.** Flowchart for the literature search

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14 591 **Figure 3.** Eligibility criteria

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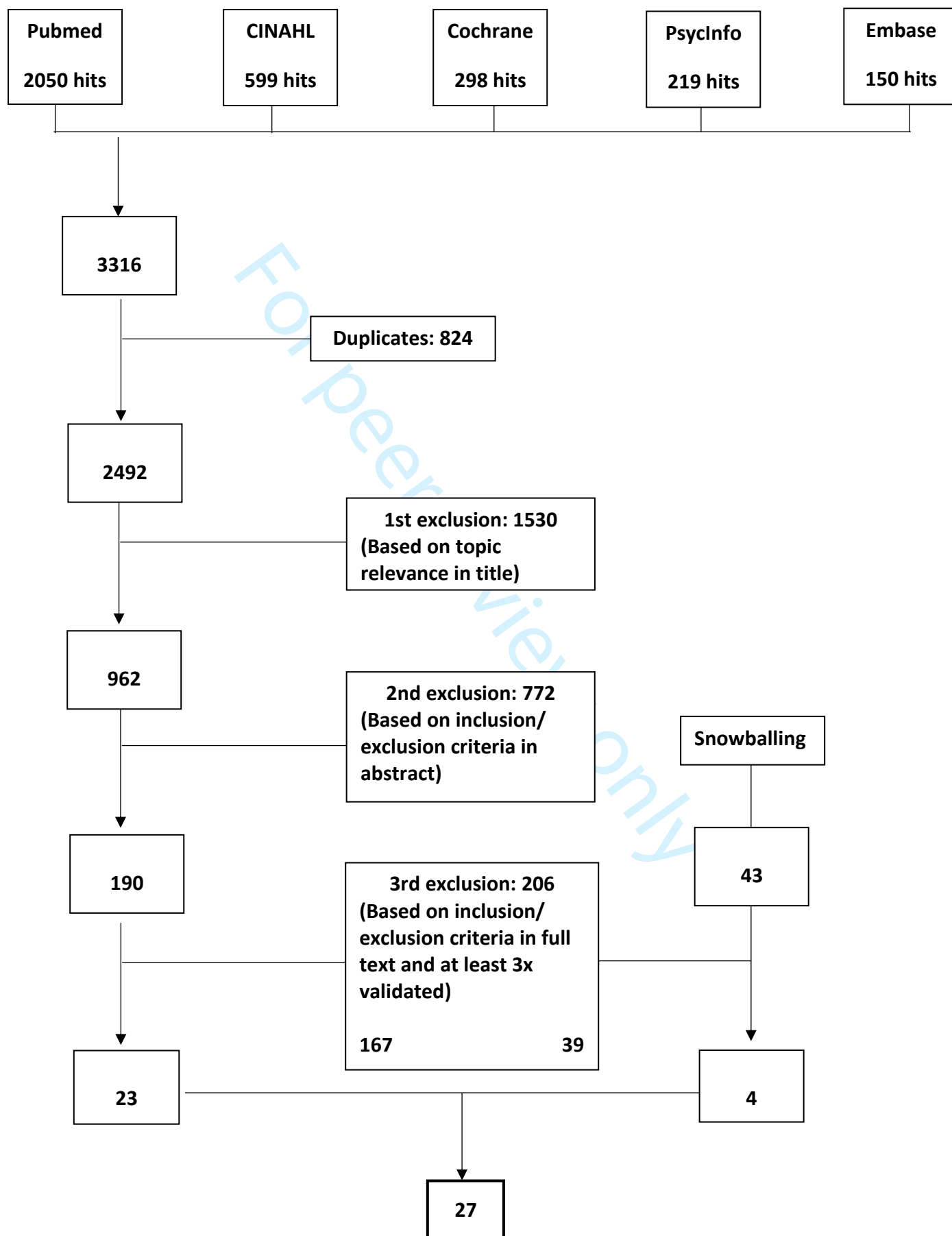
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For peer review only

**Figure 1.** Search keywords

(Frail Elderly[Mesh] OR Aged[Mesh] OR Frail Elderly\* OR Aged\*)  
AND  
(Accidental Falls[Mesh] OR Accidental Falls\* OR Falls\*)  
AND  
(Risk Assessment[Mesh] OR Prognosis[Mesh] OR Diagnosis[Mesh] OR Risk  
Assessment\* OR Prognosis\* OR Diagnosis\* OR Screening\* OR Prediction\*)  
AND  
(Specificity and Sensitivity[Mesh] OR Data Accuracy[Mesh] OR Sensitivity\*  
OR Specificity\* OR Accuracy\* OR Validity\*)

Figure 2. Flowchart Literature Review





**Figure 3.** Eligibility criteria

Articles were included when they met the following inclusion criteria:

1. Prospective studies in which the primary or secondary purpose was to evaluate the performance of one or more fall risk assessment tools for predicting fallers.
2. The participants were older people living in the community or substantially independently
3. Full articles published in English, Dutch or German

Articles were excluded when they met one or more of the following exclusion criteria:

1. Fall risk assessment tools which require expensive computer software programs, other advanced expensive software or instruments not available in usual primary care units (e.g. sensors, electronical platforms, force plates).
2. Literature reviews and studies with no follow up of fall incidents.
3. No reported Area Under the Curve (AUC), sensitivity or specificity of the fall risk assessment tools.
4. Assessment tools specifically developed for or only tested on populations with a specific disease (e.g. cancer, diabetes, Parkinson etc.)
5. The participants were living in hospital or other institutionalised settings

Additional file 1

Recent queries in pubmed

Search,Query,Items found,Time

#1,"Search (((("Aged"[Mesh]) OR "Frail Elderly"[Mesh] OR Aged\* OR Frail Elderly\* OR Elderly\*)) AND ("Accidental Falls"[Mesh] OR Accidental Falls\* OR Falls\*)) AND (((Risk Assessment"[Mesh]) OR "Diagnosis"[Mesh]) OR "Prognosis"[Mesh] OR Risk Assessment\* OR Diagnos\* OR Prognos\* OR Screen\* OR Predict\*)) AND (((Sensitivity and Specificity"[Mesh]) OR "Reproducibility of Results"[Mesh]) OR "Data Accuracy"[Mesh] OR Sensitivity\* OR Specificity\* OR Accuracy\* OR Reliab\* OR Valid\*) Filters: Full text

Publication date from 2000/01/01 to 2020/07/01

Field: Title/Abstract,1956,03:40:44

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## Additional file 2.

### Overview characteristics included articles

Author	N	Age (range, mean, SD) <sup>1</sup>	Gender	Exclusion	Inclusion	Follow up in months	Included instrument <sup>2</sup>
Alexandre et al., 2012 [29]	60	≥60 (60-82)	29 men/ 31 women	PD, history of transitory ischemic attack, stroke, cognitive impairment, wheelchair, fall in the previous 6 months	n.a.	12 months	TUG test
Bizovska et al., 2018 [48]	131	≥60 (mean 70.8, SD 6.7)	23 men/ 108 women	Any injury or surgery on the musculoskeletal system during the last two years before the baseline measurement	Aged ≥60; ii) no known neurological or musculoskeletal problem that may affect gait or balance abilities; iii) ability to stand and walk without any assistance and assisting device	12 months	POMA-B POMA-G
Bongers et al., 2015 [43]	352	≥70 (mean 76.2 (SD 4.3)	all women	too ill to be screened by GP, currently receiving treatment from geriatrician or received comprehensive geriatric assessment in past 3 months	n.a.	12 months	Gait speed test (4m)
Bongue et al., 2011 [30]	1759	≥65 (65-95, 70.7 (SD 4.6))	862 men/ 897 women	neurological disease, cognitive impairment, unable to understand French or follow simple commands	n.a.	12 months	TUG test
Chow et al., 2019 [42]	192	≥65 (mean: 74.4)	81 men/ 111 women	n.a.	aged ≥65, being discharged from the ED, English speaking, had capacity to give consent, and personally identified a risk factor for falling (if a patient reported that they had either fallen in the last year, worried about falling, or admitted that they felt unsteady when standing or walking)	6 months	TUG test
Coll-Planas et al., 2006 [51]	192 (268 with 76 drop-outs)	≥65 (89 >83 years, 103 ≤83 years)	34 men/ 158 women	living in nursing home	Community dwelling elderly aged ≥65	12 months	Fall history
Ersoy et al., 2009 [47]	125	≥50 (50-79, 61.4 (SD 7.9)	all women	unable to walk without assistance or aids	postmenopausal community dwelling women aged 50+	6 months	BBS

Faber et al., 2006 [49]	72 (total 245)	84.9 (SD 6.0) (of total 245)	14 men/ 58 women	in ability to walk 6m with(out) aids, capacity to understand instructions, medical contraindications to participate, cognitive impairment	n.a.	10 months	POMA-B POMA-G
Gerdhem et al., 2005 [52]	984	75 (75.01-75.99)	all women	n.a.	community dwelling women aged 75 in Malmö	12 months	Fall history
Hofheinz et al., 2016 [31]	120	≥60 (60-87, 72.2 (SD 6.8))	26 men/ 94 women	cognitive limitations, neurological or musculoskeletal diagnose	able to walk 10m with(out) aid, able to understand instructions, able to carry glass in one hand	12 months	TUG test
Kang et al., 2017 [33]	541	≥60 (67.4 (SD 5.6))	234 men/ 307 women	Inability to perform the basic activities of daily living and thus could not complete performance-based assessments; visual impairments; current use of drugs (psychotropic drugs, cardiovascular drugs, hypoglycemic agents, non-steroidal anti-inflammatory drugs, analgesics, dopaminergic drugs, PD's drugs or more than four kinds of complex drugs).	Aged ≥60 years and joined the China's national free physical examination programs	12 months	TUG test Gait speed test (4m)
Kang et al., 2018 [32]	619	≥60 (60-86, 67.4 (SD 5.6))	262 men/ 357 women	Severe functional impairment, current use of sedative drugs, antiepileptic drugs and so on, refusal to participate in the follow-up of this study	Aged ≥60, who joined the free physical examination program	12 months	TUG test
Kojima et al., 2015 [34]	259	≥65 (72.6 (SD 5.9))	95 men/ 164 women	≥3 falls in past year, unstable medical conditions, already exercising 150min/week	aged ≥65 able to walk independently and participate in group exercise	6 months (24 weeks)	TUG test
Lin et al., 2004 [35]	1200	≥65 (73.4 (SD=NR))	709 men/ 491 women	NR	NR	12 months	TUG test FR test
Lindeman et al., 2008 [53]	65	≥65 (67.7 (SD 6.0))	33 men/ 32 women	use of walking aid, self-reported neurological disorders, or spinal or lower extremity joint pain interacting with stepping performance, inability to come to the research department without help, cognitive impairment	community dwelling elderly aged ≥65	12 months	Fall history

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1 2 3 4 5 6 7 8 9 10 11 12 13 14	Melzer et al., 2010 [36]	98	≥65 (65-91, 78.4 (SD 5.7))	26 men/ 72 women	serious visual impairment; inability to ambulate independently; cognitive impairment; severe focal muscle weakness or paralysis; severe peripheral or compression/entrapment neuropathies; symptomatic orthostatic hypotension, respiratory, cardiovascular, musculoskeletal or neurological disorders that might have interfered with participation in the exercise program; cancer, metastatic or under active treatment; and use of medication known to impair balance or strength.	n.a.	12 months	TUG test BBS
15 16 17 18	Muir et al., 2008 [46]	187	≥47 (47-90, 79.4 (SD 5.83))	122 men/ 65 women	n.a.	community dwelling veterans of WWII and the Korean War residing in 3 regions of southwestern Ontario	12 months	BBS
19 20 21	Murphy et al., 2003 [50]	50	≥60 (72.3 (SD 8.6))	13 men/ 37 women	no exclusion based on disease	community dwelling elderly aged ≥60	14 months	FR test
22 23 24 25 26	Nitz et al., 2013 [54]	449	≥40 (40-80, 59.3 (SD 10.6))	all women	n.a.	independently mobile and cognitively competent women from the electoral rool in North Brisbane Health district	108 months (9 year)	Fall history
27 28 29 30 31 32 33 34 35 36 37 38 39	Ollsen Möller et al., 2012 [37]	153	≥65 (66-94, 81.5 (SD 6.3))	51 men/ 102 women	n.a.	Age ≥65, living in the municipality where the study was conducted; needing help with at least two activities of daily living (ADL); admitted to hospital at least twice or with at least four contracts with outpatient or primary healthcare during the previous 12 months; being able to communicate verbally and have not cognitive impairments (i.e. ≥25 MMSE)	12 months	TUG test

Pai et al., 2010 [38]	13	≥65 (65-85, 72 (SD 5))	9 men/ 4 women	musculoskeletal, neurological, cognitive or other systemic disorders, osteopenic or osteoprotic, cognitive impairment, symptomatic postural hypotension	ambulatory community dwelling elderly	9-32 months	TUG test
Russell et al., 2008 [39]	344	≥60 (75.9 (SD 8.5))	106 men/ 238 women	n.a.	community dwelling elderly aged ≥60 presented to an ED as a result of a fall being directly discharged home following emergency care and able to walk independently	12 months	TUG test FR test
Tiedemann et al., 2010 [55]	362	≥74 (74-98, 80.25 (SD=4.5))	128 men/ 234 women	blindness, minimal English language skills, and cognitive impairment	community dwelling elderly aged 63-95 resided in Sydney, Australia	12 months	Fall history
Trueblood et al., 2001 [40]	180	≥60 (60-96, 77.9 (SD 7.26))	37 men/ 143 women	cognitive deficits, underlying neurological problems	aged ≥60, able to stand for 5 min. without aid, able to walk 40 feet at one time without aid.	19 months	TUG test POMA-B POMA-G
Tsutsumimoto et al., 2013 [44]	59	≥65 (Non-fallers 84.0 (SD 1.1) 85.5 (SD 1.4))	11 men/ 48 women	very severe cardiac, pulmonary, musculoskeletal, or neuropathological disorders associated with inability to step safely, cognitive impairment	community-dwelling older people receiving long-term care services aged ≥65, able to walk independently, and having adequate hearing and vision	12 months	Gait speed test (4m)
Verghese et al., 2002 [45]	59	≥65 (Nonfallers 79.7 (SD 6.6) Fallers 79.4 (SD 5.7))	25 men/ 34 women	severe visual loss interfering with completion of neuropsychological tests, non-English or non-Spanish speaking, institutionalization, healthy enough to make a clinic visit	community dwelling elderly aged ≥65	12 months	Gait speed test (4m) POMA-B

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Wrisley et al., 2010 [41]	35	60-90 (72..9 (SD 7.8))	17 men/ 18 women	cognitive impairment, history of osteoporosis, recent fractures, or lower-extremity surgery; history of progressive neuromuscular disorder; history of whiplash, neck injury, or current complaints of neck pain; history of unstable agina or uncontrolled cardiorespiratory problems; taking any medications that might affect balance; history of any fall in past 6 months and more than one fall in the last year; pain in any segment greater than 2/10 on a 10-point verbal analog scale; not returning the monthly fall calendar	community dwelling elderly aged 60-90 able to stand independently longer than 1 min.	12 months	TUG test
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<sup>1</sup> range, mean, SD: only described when reported in included article  
<sup>2</sup> TUG test: Timed Get Up and Go test  
POMA- B: Performance Oriented Mobility Assessment –Balance  
POMA-G: Performance Oriented Mobility Assessment –Gait  
BBS: Berg Balance Scale  
FR test: Functional Reach test



# PRISMA 2009 Checklist

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Section/topic	#	Checklist item	Reported on page #
<b>TITLE</b>			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	Title, page 1
<b>ABSTRACT</b>			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	Abstract, page 2
<b>INTRODUCTION</b>			
Rationale	3	Describe the rationale for the review in the context of what is already known.	Background, page 3
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	PICO: Background, page 3 S: Methods, Analysis/Figure 3
<b>METHODS</b>			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	N/A
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g. years considered, language, publication status) used as criteria for eligibility, giving rationale.	Methods, Figure 3
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	Methods, Study selection
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Methods, Figure 1
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	Methods, Eligibility criteria and study selection
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	Methods, Eligibility





# PRISMA 2009 Checklist

			criteria and study selection
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	Methods, Analysis
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	Methods, Quality appraisal
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	N/A
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I <sup>2</sup> ) for each meta-analysis.	N/A

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Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	N/A
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
<b>RESULTS</b>			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	Methods, Figure 2
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	Additional File 2
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	Results, Table 1
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	N/A
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	N/A
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	N/A
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
<b>DISCUSSION</b>			



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Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	Discussion, page 8-10
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	Discussion, Limitations
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	Discussion, page 8-10
<b>FUNDING</b>			
Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data), role of funders for the systematic review.	Declarations, Funding

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: [www.prisma-statement.org](http://www.prisma-statement.org).

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